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CRITICAL PATH MANAGEMENT  
FOR  
CONSTRUCTION OFFICES

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Submitted in partial fulfillment  
of the requirements for the degree of

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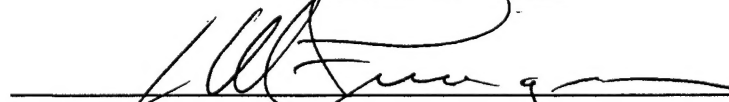
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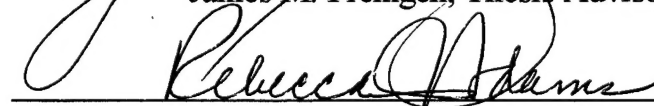


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## **ABSTRACT**

The objective of this thesis is to increase efficiency in the administration and control of defense construction contracts managed by Resident Officer In Charge of Construction offices. There are very few tools to guide the project managers in the field, where the design and construction is actually taking place, thus, they improvise individually in ways that may be inefficient. The major focus of this thesis is to explain critical path management and how it can help the project manager reduce costs, reduce time delays and increase quality. All the needs of a typical construction contract are summarized in a network schedule, using project management software to organize and control all the tasks in a project. The model is illustrated by applying it to an actual Navy construction contract. The costs and benefits of using the current methods of administration and the critical path management method using the model are then compared.



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## **I. INTRODUCTION**

### **A. BACKGROUND**

In today's cost cutting atmosphere it is necessary to increase our efficiency in all defense programs. The Department of Defense has many rules and regulations to administer and control military construction contracts on the macro level, but very few tools to guide the actual Project Manager out in the field where the design and construction is actually taking place.

In the Navy, the Civil Engineer Corps (CEC) manages and controls all construction, renovation and maintenance projects on Navy and Marine Corps bases. These projects are contracted out to civilian contractors who actually perform the design and construction. A Navy junior CEC officer is the Project Manager, who controls and administers the contract. Usually these officers have multiple contracts at one time.

In today's Total Quality Leadership environment, the focus is on streamlining all operations and directing all efforts of the organization toward serving the customer who will be using the final product. In the Resident Officer in Charge of Construction Office, young inexperienced Navy CEC officers want to follow the Total Quality Leadership concept; but they are not given any specific project management tools. Some project management training is conducted at the Civil Engineer Corps Officer School, but it is brief. With multiple projects and no consistent project management tools or techniques implemented, contracts are commonly over budget, late, and of poor quality.

A common project management technique called critical path management is a very effective way to plan, organize, execute, and monitor construction contracts. Given a simple

model to follow, the Navy officers who are the Assistant Resident Officers in Charge of Construction will be able to apply critical path management to save the government time and money.

## **B. OBJECTIVE**

This objective of this thesis is to: (1) explain how critical path management can help the Assistant Resident Officer In Charge of Construction, (2) develop a critical path management model, (3) illustrate how it is used with an actual government construction contract, and (4) perform a brief cost/benefit study to determine if using critical path management techniques and the model saves the government's valuable resources.

## **C. RESEARCH QUESTIONS**

The following specific questions are addressed in this research:

1. Is critical path management an effective, efficient, consistent method to manage and control a typical construction contract?
2. Is critical path management, combined with project management software, useful for developing a standard model for a "typical" construction contract? How does it work?
3. Is the CPM method with a standard model more efficient and cost effective than other informal manual methods typically used by a Resident Officer in Charge of Construction Office?

## **D. SCOPE, LIMITATIONS, AND ASSUMPTIONS**

The main purpose of this study is to develop a very basic construction model using critical path management techniques and project management software. This thesis will be limited to briefly explaining how the model was developed, illustrating the model with an

actual construction project, testing its cost effectiveness by using a cost/benefit analysis, and briefly discussing its implementation. In the end this thesis will serve as a handbook for Assistant Resident Officers in Charge of Construction so they can effectively and consistently manage construction projects and understand the basic project management concepts.

There are extraneous factors that limit the research effort. Costs will be difficult to determine since the model has never actually been used. Actual costs for the illustrated construction project using current techniques are not readily available and would be difficult to include completely in the scope of this thesis. Some forecasting will be used to determine basic costs using the model; however, forecasting is not completely accurate.

In this thesis it is assumed this model will be used in a Resident Officer In Charge of Construction office that has compatible computer technology and personnel trained to use basic programs. It is also assumed the reader understands basic project management concepts.

## **E. LITERATURE REVIEW AND METHODOLOGY**

The methodology by which data was collected for this thesis consisted of interviews, literature searches, and collection of official contract data. The Resident Officer in Charge of Construction at the Naval Postgraduate School was interviewed briefly about current policies and procedures. Current periodicals and recent book publications were used to choose software and develop the model. Official contract documents were used to develop an illustration of the model and perform the cost/benefit analysis.

## **F. ABBREVIATIONS**

Some common abbreviations used throughout this thesis are:

CEC - Civil Engineer Corps

ROICC - Resident Officer In Charge of Construction

AROICC - Assistant Resident Officer In Charge of Construction

CPM - Critical Path Management

PM - Project Manager

TQL - Total Quality Leadership

PERT - Program Evaluating Research Task

## **G. THESIS ORGANIZATION**

The remainder of this thesis is presented in four chapters with supporting appendices.

Chapter II presents a general discussion of critical path management, development of the construction model, and its use.

Chapter III illustrates the implementation of the model by using an actual contract at the Naval Postgraduate School.

Chapter IV is a cost/benefit study comparing the current method of contract administration and the proposed CPM method with the developed model.

Chapter V provides the conclusions and recommendations of this study. Conclusions are drawn from the model and the cost/benefit study. Recommendations are made regarding implementation and the various uses of critical path management and the model.

The appendices present the basic model and the example used to illustrate the model.

## **II. CRITICAL PATH MANAGEMENT**

### **A. SPECIFIC BACKGROUND**

All construction, renovation and maintenance projects for Navy and Marine shore facilities are managed by the Civil Engineer Corps (CEC) . The contracting process is under the authority of an Engineering Division headquarters which presides over a geographical area. In each division there are multiple field offices which handle the actual contract administration on site. The field office is the Resident Officer In Charge of Construction (ROICC) and the officer in charge is normally a Lieutenant Commander. The Assistant Resident Officer in Charge of Construction (AROICC) is the junior officer who is actually the project manager who handles the administration of assigned contracts.

The AROICC's job begins when a contract is advertised in the civilian community. The AROICC is responsible for the review of the contract specifications and drawings for constructability. Once the contract is awarded to a contractor, the AROICC becomes the project manager who is responsible for the proper execution of the contract work. Specifically, the AROICC is responsible for all aspects of the job, including planning, approving submittals, coordinating work schedules, solving design problems, and accepting work in place. AROICC's usually are in charge of multiple projects at any one time.

A construction project can vary in complexity from a simple \$25,000 playground to the construction of a multi-million dollar office building complex. As is to be expected, these projects can get very complicated, require enormous amounts of information, and take a great deal of work to administer and control. The average ROICC office does not have any

formal control procedures for the AROICC's to effectively and consistently administer the projects. Each AROICC has his or her own management style. At the start of a project, a paper file is usually created and organized according to the AROICC's particular preferences. The AROICC knows what to expect from the contractor from the specifications and preconstruction meetings and expects to receive all the necessary information on time. Usually the experienced contractor will eventually submit all the required documentation, which is reviewed, approved and filed in the paper file. During actual construction the AROICC will try to keep track of the contractor's progress and help when problems arise. Each AROICC has his or her own particular management techniques, but all the AROICC's interviewed for this study manually handled all the information and correspondence, trying to manage all aspects of every project under their authority. Often when a project gets complicated the AROICC gets overwhelmed trying to manage all the problems and tasks of multiple projects. The contractors are rarely held accountable for a submittal process or a realistic schedule. Time and money are wasted and the quality of the final product is compromised. The lack of proper planning and organized control techniques costs the government millions of dollars each year.

There is a desperate need within the CEC to develop better project management techniques. Proactive management is much more effective than the current reactive management. Proper project management includes four phases, planning, organizing, executing and monitoring, and includes the project elements of time, cost, material and organization (Ahuja, 1994). Proper project management will allow the AROICC to plan the project and stay in control throughout the duration of the work. This will give the AROICC's

confidence in their abilities, allowing them to properly administer multiple projects resulting in quality final products.

## **B. CRITICAL PATH MANAGEMENT DEFINED**

### **1. History**

Critical Path Management is not new to the Navy or the military. It was used in the late 1950's and early 1960's to develop the Polaris Fleet Ballistic Missile system. CPM was used to develop project schedules and minimize project costs through optimized scheduling (Moder, 1993). The Program Evaluation and Review Technique (PERT) was also developed for this particular project. From this effort Gantt charts and other management reporting techniques were developed (Moder, 1993). All these management methods were characterized as largely manpower intensive or dependent on a main frame computer, which was economical only for very large complex programs.

It wasn't until the mid 1980's, when personal computers became capable of handling the extensive calculations of CPM and PERT algorithms, that CPM was considered to be a feasible management tool. Computers are even faster today, so the repetitive calculations that made CPM formidable can now be performed by a computer in seconds. These computers have made it possible for managers with only a casual understanding of CPM, PERT and Gantt concepts to use these methods to improve project management of all types of projects. Modern software has combined CPM, PERT and Gantt methods to plan, organize, control and complete construction projects easily and quickly.

### **2. CPM Defined**

Critical Path Management is a project management technique for developing a plan,



obtaining feedback during execution, modifying the plan, and attaining a goal. CPM has four phases, planning, organizing, executing and monitoring a project (Ahuja, 1994). It helps a project manager successfully use the four project elements, time, cost, material and organization. CPM in its pure form without computers is identifying tasks to complete a project, putting them in order of execution, creating interdependencies, and determining durations - all to develop a schedule. The schedule dates are calculated by using a start date and task durations and tracking through the various paths of construction until a final completion date is reached. This final completion date is determined by the longest path, or the critical path.

### **3. CPM Basic Concepts**

In today's software, CPM is used by the computer to calculate the schedule. Several common types of graphical representations are used to display the information. The project activities are inputted in a Gantt Chart (Figure 1) as individual tasks, which are then given durations and graphed as work over time. A PERT chart shows the schedule as a network and is useful for placing the individual tasks in order of execution and creating dependencies. Figure 2 shows a small section of a PERT chart. A much more extensive PERT chart is shown in Appendix A. Gantt charts combined with PERT networks are the two basic tools necessary for the start of successful project management using CPM.

Having the tools is not enough for success, however. A project manager must understand how to use the tools. In today's environment most organizations, including the

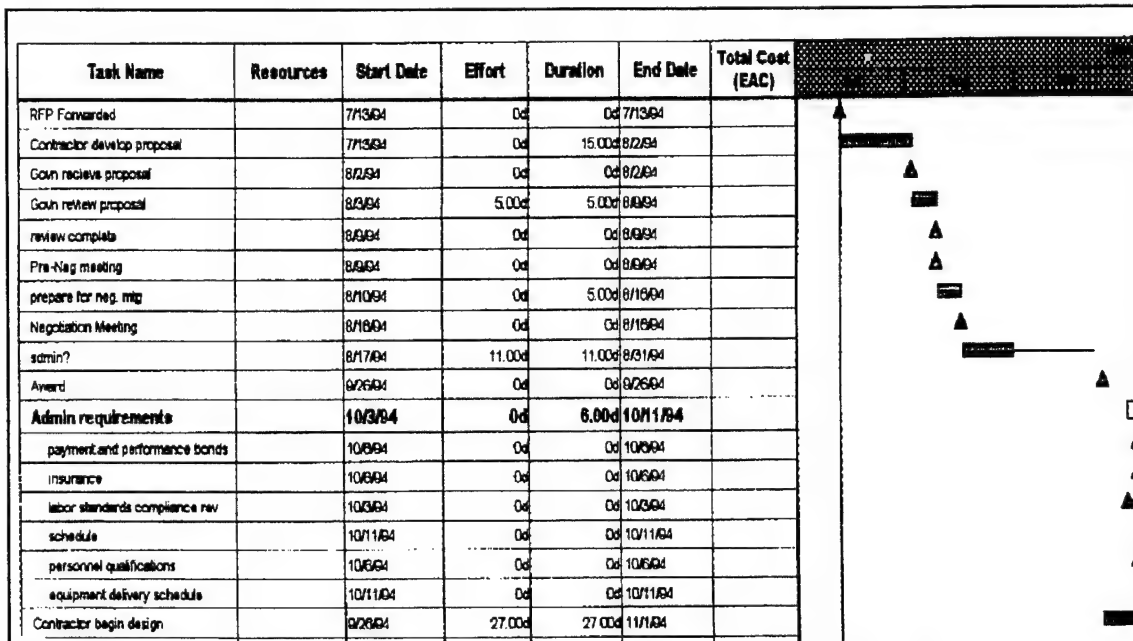


Figure 1. Gantt Chart

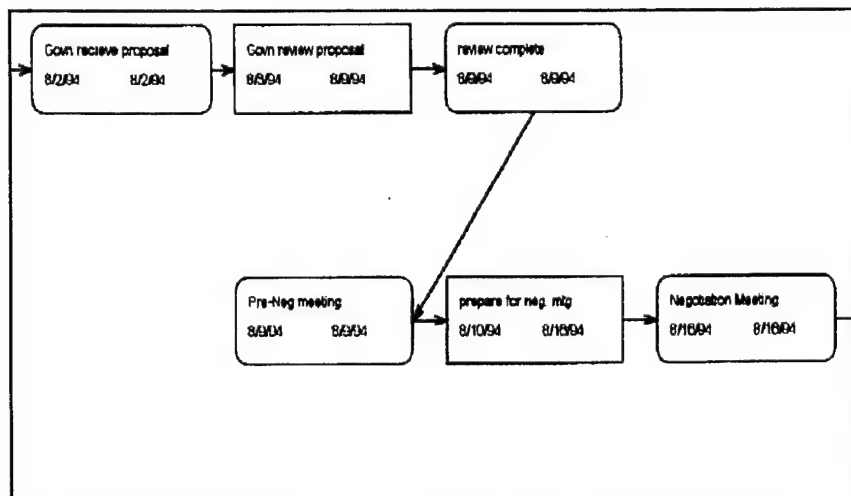


Figure 2. PERT Chart

ROICC office, must operate with some sort of plan in the form of a written schedule. Most of the time it is a simple bar chart that lists large phases of the plan and the durations which are shown on a horizontal calendar, as shown in Figure 3. As each phase is completed, another bar underneath the planning bar is filled in to show actual progress. These bar charts

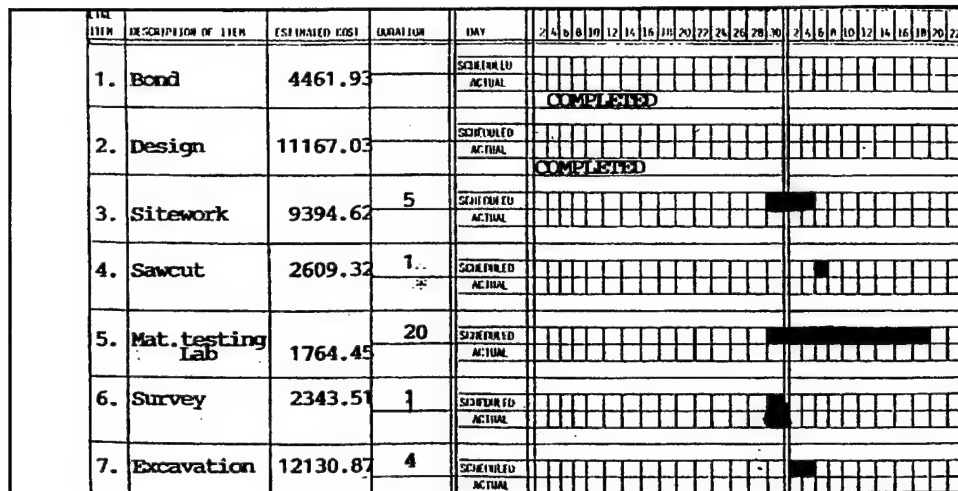


Figure 3. Bar Chart

are rarely accurate, and do not show any of the interrelations and interdependencies that control progress (O'Brien, 1993). These bar charts are usually treated by the Government and the contractor as a paperwork exercise, and are automatically approved. This bar chart schedule is the only formal means of control over the contract progress. As a result the AROICC must physically verify where the project really is in terms of its schedule.

CPM software and proper project management techniques can avoid this problem. In the beginning of the contract the AROICC uses the Gantt chart format and the official plans and specifications to input all the project tasks. These are then put in order of execution. Durations are estimated and dependencies are created. A schedule is generated

by the computer, with a realistic completion date. This schedule can then be used to track all aspects of the project from material submittals to the final installation of a new building's security system. The AROICC also has the added benefit of knowing that project inside and out because he or she had to review it step by step to develop the schedule. This is the start of planning using CPM concepts.

This first schedule is only the first attempt. Once the contract starts and the contract time clock actually starts ticking, this schedule will be constantly shifting and will require modifications. This schedule will allow the AROICC to sit down with the contractor and plan the actual construction methods and talk the project through. At this time, problems are often identified before they become serious time delay and can be solved before work even begins. The schedule can include a summary of the many milestones for when routine paperwork is due and give the AROICC an easy reference to track the submittals and their approval. During actual construction the schedule will identify what task is to be completed on what day giving the AROICC a tool to see exactly where construction should be and whether it is on schedule. It is a method of holding the contractor accountable for his work. The schedule is dynamic and requires constant communication between the different Government employees and the contractor to keep it up to date and accurate, but it helps to keep work moving on time and within budget.

One of the main drawbacks of CPM is that it takes a great deal of time. First, CPM techniques must be understood. Fortunately most AROICC's have civil engineering degrees which included some classes which briefly reviewed CPM and scheduling. Second, the time to learn the program is a factor. There is always a learning curve associated with learning

any new software. This learning process has to happen only once, though. Third, inputting the project information in the form of individual tasks takes a great deal of time and is quite repetitive and time consuming. Government contracts all have similar schedules in the beginning of a project, with the same requirements; but, once the project starts, it is unique in its particular construction. This thesis addresses this time problem. Since all contract requirements in the beginning are identical, a model will be developed using CPM software that already has the basic tasks, durations, and dependencies inputted. It also will show the general areas of construction which can easily be expanded upon once a particular project design is received.

#### **4. CPM and TQL**

Today's Navy has adopted the Deming Total Quality Management philosophy, which was changed to Total Quality Leadership to reflect the Navy's unique organizational structure. Total Quality Leadership emphasizes the elimination of waste from the workplace by examining processes. "TQL of projects involves bringing together successfully a complex mixture of ingredients consisting of teamwork culture, trained personnel, corporate mission, goals and strategies, leadership, organizational structure, and adequate project management tools" (Ahuja, 1994). TQL and CPM philosophies are closely related. Both have the goal of streamlining operations and directing all efforts to completing a project to serve the customer with a high quality product.

### **C. DEVELOPMENT OF THE MODEL**

#### **1. Software Choice**

To use CPM it is advisable to use a project management software package. Manual

calculations of durations, activity start and finish dates, and the project completion date are so cumbersome and time consuming that this method would not be practical for smaller projects. When CPM software first became available it was extremely expensive, so it was used for only large construction projects. Now many different software packages are available for only hundreds of dollars rather than thousands.

By reference to different computer magazines and their evaluations of the software for small to large construction projects it was easy to narrow the choices down to three. CASuper project by Computer Associates, Timeline by Symantec, and Microsoft's Quick project were very inexpensive and easier to use than other software packages available (PC Magazine, 1995). All three are under six hundred dollars and are fairly simple to use, although any CPM software requires some knowledge of basic PM techniques. For a small ROICC office, cost is a limiting factor. Timeline was chosen for the development of the CPM model because it was capable of handling multiple projects simultaneously. This feature could be useful later as the ROICC expertise increases and as the use of CPM becomes routine. Timeline is an ideal package for the organization with little or no CPM experience. Using the program is very easy. It has easy pull-down menus; so, once the basic learning curve is over, using the program is as simple as pointing the mouse and clicking the button on what the user wants to do.

## **2. The CPM Model**

The CPM Model developed in this thesis is a very simple network of tasks that are common to any government construction project. The information used to develop the model included a copy of an actual construction contract with the official plans and

specifications. Many sections of the contract are identical for every government project. As a result, parts of the CPM schedule will always be the same or very similar. These are the tasks that are targeted in the model, so the AROICC does not have to enter the exact same tasks every time a new project schedule is developed. Also, very general areas of a construction project are included in a very simple form so they can just be expanded upon for each individual contract. This model will make the AROICC's job easier and give him or her a place to start inputting the CPM schedule for each unique contract.

To start the model, certain criteria within the Timeline program had to be established. First the basics of a construction project had to be entered, such as number of work days, actual working hours per day, and holidays. For example, an assumed 40 hour work week and five working days were inputted and saved. Every project schedule developed using this model will now have all the standard settings. These settings are very easy to alter if necessary.

The plans and specifications for any government contract will include the complete design and all the contract requirements. After reviewing the contract documents, the Gantt chart in the database was used to type in the tasks that make up a standard project. First, all the major milestones of a contract, such as contract award, were inputted. Contract award is a milestone, or a task with no duration, that must be reached in order for the rest of the contract work to proceed. All of the milestones were then placed in the Gantt chart in chronological order as shown in Figure 1. For example, the negotiation meeting had to be completed before the award could happen. Once the major milestones had been inputted and saved it was time to go back to the beginning and insert all the contract tasks. Timeline is a

very easy program in which to insert, delete and move tasks about so tasks can be inputted and manipulated.

Inputting these tasks is not as easy as it sounds. All the tasks must be placed in the proper order, each with a successor and precessor. A precessor is a task that must happen before another can be started. A successor is a task that depends on another and cannot begin until the previous task is completed. After all the milestones are inputted, summary tasks are inserted to develop an outline of work before inputting the hundreds of individual tasks. A

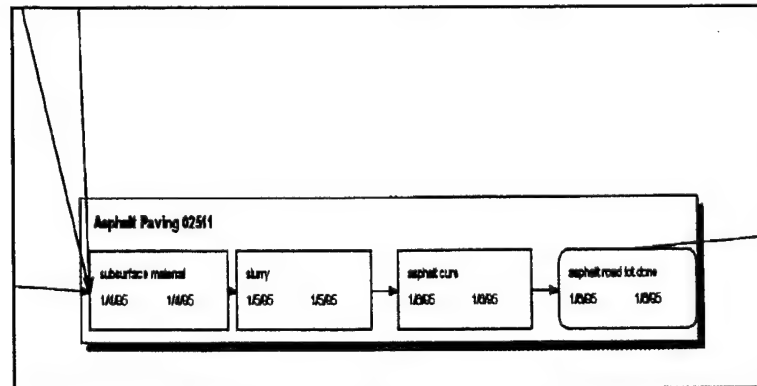


Figure 4. Summary task

summary task is one task that is used to collect a series of related tasks and indents them in the Gantt chart (Figure 1) or encloses them in a single box in the PERT chart as shown in Figure 4. These summary tasks are at a basic level of detail that shows the big picture before each part is zoomed in on and the level of detail is increased. For example, there are multiple administrative items that must be submitted by the contractor before work can begin on site. All these administrative reports are included in the model as a summary task to make the organization of the Gantt chart simpler and the PERT network diagram easier to read.



Summary tasks can also be used in the actual construction, such as asphalt paving. Paving is a summary task but many smaller individual tasks need to be done before paving is considered complete. For example, first a subsurface must be ordered, put in place, and then compacted before the paving can be done.

Once the summary tasks are in the proper order, all the individual tasks are filled in using the plans and specifications and the AROICC's personal construction experience. At this point the model is beginning to look like a simple construction project list, with all the standard tasks inputted and saved in a database, as shown in Appendix A.

The next step in the development of the model is to assign durations to each of the tasks. The summary task durations are assigned by the computer based on the individual tasks inside the summary box. It takes the earliest date to start the summary task and the latest date as the completion of the summary task. Durations for the required administrative submittals are included in the contract. For example, the proof of insurance must be submitted and approved 10 days after the award of the contract; so 10 days is inserted as the duration. Within the duration box, Timeline gives the user two different duration types to use. The first is fixed duration. Fixed duration cannot be changed no matter how many people work at the task; these are often administrative deadlines which are actual contract requirements (Sanders, 1991). The second is effort-based duration, when a task can be completed faster if more people work on it. Effort-based tasks are usually the actual construction tasks (Sanders, 1991). For some tasks it is obvious which type of duration is to be used, but others require engineering judgement. One thing to remember here is that all of the effort-based durations are estimates based on standard crew sizes.

The durations in the model for many of the administrative requirements will be the same for all construction projects but the durations for the summary tasks will usually not be the same. When a specific project is inputted, the durations for the construction tasks will be unique for that individual project.

When inputting tasks and durations, effort-based tasks will come in a few different categories based on when they will start and finish. The category must be chosen for each particular task or it will revert to the default category. The default category is the most commonly used task category. It is the As Soon As Possible (ASAP) category. These are tasks which will be accomplished at the earliest practical opportunity. Their earliest occurrence is generally constrained by the availability of a resource or completion of a prerequisite task. Other categories are As Late As Possible (ALAP), Start No Sooner Than (SNS), Start No Later Than (SNLT), and Must Start On (MSO) (Symantec Corporation, 1994). For the model, the ASAP category was used for all tasks to avoid confusion and keep the model as simple as possible. As a specific project is inputted into the model these categories can easily be customized to fit the actual sequence of project tasks.

Once all the tasks and durations were in the Gantt chart, the PERT network view was used to create dependencies and place tasks in order of completion. In the PERT view milestones are circular boxes and tasks are rectangular boxes. The PERT view makes it easy to see task relationships and determine whether tasks are concurrent or consecutive. To illustrate how this was done, part of the PERT view of the model will be examined as shown in Figure 5. Before the curing of the concrete could happen, several tasks had to be completed first, so ties were drawn in the form of activity arrows showing the flow of work.

First the reinforcing must be placed in the excavated area. Once this was completed the concrete was brought on site and was tested to make sure it met contract requirements. These are consecutive tasks. The next two tasks could be completed at the same time. These are the pouring of the concrete in different areas of the site. Each of these tasks are successors to the concrete testing task. Once the pouring is done for both of the tasks the curing could begin.

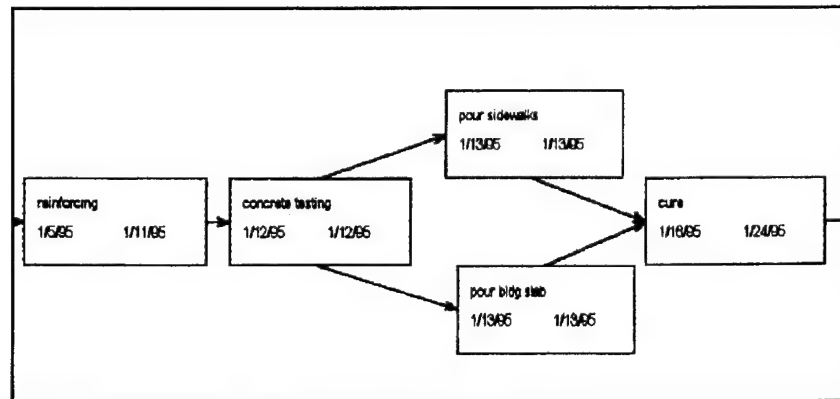


Figure 5. PERT Chart

In Timeline there are four different ways to show the relationship between tasks. For simplicity, all the tasks in the model use the default relationship. This is a finish-to-start relationship between tasks. It means one task must be finished before another can start. (Symantec Corporation, 1994) It is the most commonly used relationship in construction scheduling. A less common relationship available in the program is the start-to-start, where the successor starts at the same time the predecessor task begins. The start-to-finish is also uncommon. This is where a task must be started before another task can be completed. The end-to-end relationship is not very common. Here both tasks must end simultaneously or there is a specified time relationship between their completion. When using the model for a

specific project, these relationships can be easily customized to show the most accurate relationship.

Timeline makes it easy to move tasks around the page and place them in logical order. Connecting tasks is also simple within the PERT view. The most time consuming part of developing the model is placing tasks in order of execution and interpreting the contract documents to find the proper time requirements for the various submittals.

At this point the model is as complete as it can get without actual construction dates, as shown in Appendix A. Calculation of the schedule and more advanced concepts will be illustrated in the next chapter. It is important to note that to print the model example, dates were inserted. Developing the model took time and construction experience; but, once the basic milestones and administrative items were entered, their tasks, durations and dependencies will not change for most projects. The model shows some basic construction tasks in the form of summary tasks which are in logical order, allowing the AROICC to tailor the model to develop a useful CPM schedule.

#### **D. USE OF THE MODEL**

This model has the potential to save every ROICC office time and money. It is a starting point for every single construction project. Most of the basic milestones and the administrative and submittal requirements are the same for every contract, so these will never have to be re-inputted unless Government requirements change. The AROICC will be the primary person using the model. He or she will use it to develop a preliminary construction plan before the preconstruction meeting. All the AROICC will have to do is enter the model, save it under another name, and start modifying the construction portion of the plan to fit the

particular project. Once this particular plan is inputted the AROICC has already built the project on paper and is ready to enter the preconstruction meeting and talk over the project with the contractor.

At this time the schedule developed is only an estimate to be used as a tool to plan actual work. It will change many times, starting with the preconstruction meeting. The contractor has the expertise to build the project so the AROICC must realize he or she should listen to the contractor's ideas and plans and then modify the CPM plan. Throughout the project this CPM schedule will be dynamic, needing to be updated regularly. As the project progresses, the ROICC staff will use it to hold the contractor accountable for deadlines and to administer the project. Details of the use of the CPM schedule will be discussed in Chapter III.

As the use of the model and the CPM method become more prevalent, a historical file will be developed automatically. At the end of each contract the AROICC will have a final as-built CPM schedule with actual durations and construction methods. Later when a similar project is awarded, this prior schedule will be an excellent reference to develop a more accurate preliminary plan.

#### **E. SUMMARY**

The current methods of contract administration are not adequate in today's cost cutting atmosphere. Critical path management with the developed model is a powerful contract management tool which can help the AROICC decrease costs, reduce time and increase quality.

### **III. NPS GATE CONSTRUCTION CONTRACT**

#### **A. BACKGROUND**

To fully explain the CPM model that was developed in Chapter II, an actual contract from the Naval Postgraduate School will be used. The main gate and guard house were recently completed using a design-build contract. This type of contract is awarded to a contractor who will be responsible for designing the project and then building it. The data collected for this thesis was obtained during interviews, official contract documents, and the plans and specifications.

#### **B. SCOPE OF WORK**

The scope of work was to design, construct and manage the new main gate at the Naval Postgraduate School. As stated in the contract documents, "The project consists of site improvements to include partial demolition of an existing parking lot, a new Tenth Street entrance roadway, a guard house, installation of two wrought iron gates, an architectural wall and security fencing." The Contractor was required to design and build the main gate and the surrounding structures.

#### **C. ACTUAL ADMINISTRATION OF CONTRACT**

The administration of a contract begins at the Engineering Field Division, which develops the project and prepares the official contract documentation for solicitation. The ROICC office takes over the contract formally when the contract is awarded. However, the ROICC is usually invited to attend any pre-award informational meetings. In the ROICC office the AROICC is assigned as the Project Manager (PM) responsible for all aspects of a

contract, and is the liaison between the contractor and the Government. There is a civilian engineering technician assigned to each project who acts as the daily inspector, and routinely checks on the contractor's progress. This engineering technician reports to the AROICC on a daily basis. There is usually one contracting officer per ROICC office who signs all the official administrative documents and handles all the official monetary details .

#### **1. Pre-award**

To start the contracting process the Engineering Field Activity (EFA) sent a Request For Proposal (RFP), along with all the necessary technical information, to the contractor chosen by the Engineering Field Activity. For this contract the RFP was sent to the contractor on 13 July 1994 with the due date for the proposal set for 2 August 1994. Even though the ROICC office was not officially involved at this time, the ROICC usually takes the time to get the contract documentation organized. This particular contract was organized using a six file folder system. File 1 was pre-award documents, file 2 was for post-award documents, file 3 was labor compliance documents, file 4 was payment documentation, file 5 was for submittals and file 6 was the modifications file. The AROICC also kept a black notebook with the contract requirements, notes, and the approved plans and specifications. A program named Paradox is used to summarize all of the ROICC office contracts and critical data, including the gate contract data. Correspondence for all current and past contracts is kept on a personal computer.

Before the proposal due date this particular contractor requested a meeting to clarify details of the contract requirements. The Engineering Field Activity representative, AROICC and other government representatives attended this meeting. It was mainly a question and

answer session concerning the scope of work. The proposal was submitted on time on 2 August 1994. If the proposal is not received on time, the contractor takes the risk of being eliminated as the possible contractor and having the government advertise the work for other contractors to bid on.

The proposal is sent to the Engineering Field Division for review by the Engineers and contracting experts to prepare for negotiations. A copy is routed around the ROICC office using a typed routing slip for the Contracting Officer, ROICC, AROICC, and technical representative to review. This routing slip requires an initial to show each person has seen it. There are no deadlines for each review.

There was a pre-negotiation meeting with the contractor by the EFA and ROICC personnel to clarify any confusing portions of the proposal. This meeting occurred on 8 August 1994. The negotiation meeting took place on 11 and 12 August 1994. At this meeting Government and contractor personnel reviewed the requirements of the contract, reviewed the proposal and came to a final price agreement.

After the agreement there was extensive paperwork to complete, so award was scheduled to take place several weeks later on 26 September 1994. At this time the contract requirements had to be modified. Because this modification was not signed until 6 October 1994, the contract was not actually awarded until 8 October 1994.

## **2. Post-award**

Once the award takes place the contract is the AROICC's responsibility. After the award the contractor has fifteen days to get organized to begin work. At the fifteen day mark the contract clock starts ticking. The contract was split into three phases for scheduling:



design completed by day 35, Government review of the design completed by day 50, and construction completed by day 175. This put the final design due date at 31 October 1994, government review complete by 14 November 1994, and the contract completion date at 4 April 1995.

On the award date the AROICC begins administering the contract. There are numerous details and deadlines for every contract and the gate project was no exception. Many submittals are due within days of the contract award. For example, the contractor is required by the contract to submit a contract schedule to the Government within 15 days of award. This schedule is required to be in a critical path format and cover the entire contract from start to finish. The AROICC for the gate project did not have any summary of requirements and due dates prepared, so it was difficult and time consuming to determine what was due and when. As a result, few of the initial required submittals were turned in on time. Instead the AROICC and the contractor concentrated on getting the design started and ignored the smaller details which had little noticeable impact on the design.

### **3. Design**

Within ten days of award the contract requires a pre-construction meeting to discuss the project. This meeting was held on 11 October 1994 and attended by key Government and contractor personnel. At this time details such as obtaining base passes, submitting proof of insurance, and other general administrative requirements were also discussed. Contractor questions about the scope of work and the design were answered. The contractor was also verbally reminded of design completion deadlines. The AROICC ran this meeting which lasted a few hours.

Once the contract time began, within 15 days a 35% review of the design was required by the contract. This 35% review is a meeting at the contractors office with the AROICC and the technical representative to discuss the design and answer the contractor's questions. The final design was due on 28 October 1994. It was actually submitted on 7 November 1994 and disapproved by the AROICC because extensive revisions were necessary. The contractor had failed to submit a complete design. The final design was given a new due date of 17 November 1994, was actually submitted on 5 December 1994, and was once again disapproved. A 100% design review meeting was actually held on 15 December 1994. Notice to proceed with the construction was finally given to the contractor on 11 January 1995, six weeks after the original planned notice to proceed date.

#### **4. Construction**

At this point the contractor is formally allowed to begin construction after a second preconstruction meeting and the approval of various required submittals. This meeting was similar to the first. It took several hours in which construction requirements were discussed and contractor's questions were answered. In the contract requirements, on-site work is absolutely not allowed until several administrative requirements have been submitted, including schedule, safety plan, schedule of prices, and insurance. Most of these documents were due 15 days after award of the contract. These requirements were not all enforced since on-site work began 30 January 1994 without all the required submittals being approved.

Once construction began, the project proceeded at an acceptable rate. Eventually all the required documents were submitted. During construction there were several delays which required modifications to the contract. Change order number one was administrative due to

changes in the wording of the contract. This change occurred in the beginning of the contract and delayed award. Change order number two was for design changes, which included adding curb ramps, changing the gates, and modifying some fixtures. Change order number three was for weather delays. Change order number four was for design and timing problems which had to be solved. It included the demolition of the old guard shack, which could not happen until the new one was operational, so the contractor requested a time extension.

Change orders often take a great deal of time and effort. The changes must be identified as actual modifications; then the contractor submits a proposal which is reviewed by the ROICC staff. The contracting officer and the contractor must come to an agreement and sign the official change order document before the contractor can do any of the required modifications. As a result, work is often delayed.

The contract was officially completed and turned over to the government on 16 June 1995. Since the contractor was very late in finishing the design and encountered construction changes, the entire project finished 10 weeks later than the original contract completion date of 4 April 1995.

#### **D. IMPLEMENTING THE MODEL**

Using the gate project as an example will clarify the model's (Appendix A) actual use in contract administration (Appendix B).

##### **1. Pre-award**

The ROICC has very little control over the contract before the contract is awarded. While awaiting the award the AROICC can use this valuable time to become familiar with the contract requirements by using the model to develop a preliminary schedule and attending

informational meetings held by the EFA for the contractor.

*a. Developing the Preliminary Schedule*

Using the model is very simple once the AROICC is familiar with Timeline. The first step is to thoroughly read over all available documentation for the gate project, and become familiar with the scope of work and requirements. Once all the data is gathered it is time to start using the model (Appendix A). The next step is to enter the model in the Gantt Chart and save it under a different name such as "Gate". This way the data in the model can be modified for this particular project without changing the original model. The next step is to check all the early tasks and milestones and make sure they are all included in the network with all the proper deadlines and durations. If they are not, this is the time to add or delete tasks. Once the tasks and durations are entered it is easiest to work with a PERT chart. The application of the model in Appendix A will be explained step-by-step. Appendix B is the result of changing the model for the gate project. For example, on page 61 of the model in Appendix A, the sequence of events shows the RFP forwarded, proposal received, government review, prenegotiation meeting, negotiation preparations, negotiation meeting, administrative tasks, and award. The gate contract in appendix B is identical since it was used to develop the model. If the model was used for another contract all these tasks would be similar. The only major change would be the dates. The AROICC would insert the dates unique to the individual contract.

In Appendix A, page 62, the administrative requirements are shown on one path of the project. Once again Appendix B, page 70, of the gate project is very similar since the administrative requirements for most contracts are identical. This must never be taken for

granted though; the AROICC must check the individual contract specifications for the actual requirements and compare them to the model's requirements. For example, after the award the contractor is required to submit a schedule for the project. The model allows 15 days for the submission of the schedule. It is important to check the gate project contract and make sure the duration is actually 15 days. The other path in Appendix A, page 62 and Appendix B, page 70, shows the progression of the design task by task. Once again it is identical and requires no revision.

The Gantt chart in Timeline is very easy to revise, and the PERT chart makes it easy to analyze the schedule. Usually the early requirements from RFP to the Notice To Proceed (NTP) for a project will be either identical or very similar to the model in logic. Revising this part of the model to develop a schedule will take very little time.

The schedule after the NTP will be unique for every project, and the project will start to get complicated. In Appendix A, page 63, the NTP is where different paths of construction emerge. The model at this point will still resemble the "typical contract" since most contracts have the same administrative requirements and similar mobilization requirements. As shown in Appendix B these administrative and mobilization tasks for the gate project are still identical to the model's in appendix A. There are many administrative requirements due before work on site can begin; so it is necessary to check these to make sure they are all included with the proper durations. In the model there is an additional path which includes material submittals. In the model these submittals are kept separate, but once a project schedule is being developed it is best to move each individual material submittal to the summary task to show the relationship. For example, in Appendix A, page 64, the first

material submittal is the electrical submittal. When the project was inputted, this submittal task was moved to be in sequence with the laying of electrical conduit (Appendix B, page 72). This makes the network easier to read.

The next step is for the AROICC to review the contract documents, and use his or her engineering knowledge to forecast how he or she would build the project if the AROICC was going to design it. Remember, at this point there is no design yet, only a scope of work. This forecasting should be very basic and not broken down into individual tasks. The best way to do this is review the model's PERT chart (appendix A) task by task and note which tasks are already included. For example, general concrete work is already inputted in Appendix A, page 65. The AROICC should use his or her engineering judgement and add any necessary general tasks that are unique to the contract. In the gate project, even before the design is completed, the AROICC knows the required architectural wall will have footings which will be poured concrete. At this stage that task can be inputted. Other tasks won't be so obvious yet, so it is best if the AROICC concentrates on adding or deleting summary tasks. As shown on the remaining pages of Appendix A, there are many summary tasks already inputted. The AROICC can go over all these summary tasks and quickly delete summary tasks which will obviously not be included in the gate project. At the same time the AROICC can add summary tasks which may not be in the model. At this time, revising this part of the network isn't as important as reviewing the project and getting a general idea of what to expect from the contractor's design.

The next step is to place these summary tasks in some logical order. This is easiest using the PERT chart since it is easy to see the logical sequence in a network diagram.

At this point it may be possible to expand the summary tasks into basic individual tasks, but it isn't that important yet. Establishing dependencies among the summary tasks is the next priority. At this point let the computer use the default category of start-to-finish relationships when connecting the dependencies for the related tasks. An example is where a task such as pouring concrete must be finished before concrete curing can begin (Figure 5). The other relationships available will be explained in more detail later in this chapter as the schedule is completed in more detail.

Since the government engineering technician will be the person in charge of monitoring the contractor on a daily basis, it is a good idea to talk through the preliminary schedule with him or her, and revise it if necessary. These representatives normally are civilians with extensive construction experience who can help a great deal.

At this time the model has been transformed into a very basic schedule that shows the logical sequence of major events that make up the project. The AROICC is now very familiar with the contract requirements and has a general idea of how the contract could be completed. The AROICC is now ready to begin working with the contractor immediately after award.

Since this schedule does start with the RFP, the AROICC must keep track of what is going on between the EFA and the contractor in order to keep the schedule up to date. At this time it must be emphasized this network is only a preliminary schedule which shows how the AROICC would complete the job if the AROICC were the contractor. It is not binding or final, and the AROICC must keep in mind the government is purchasing the contractor's expertise; so this schedule is not even close to being accurate and complete at

this point in time.

## **2. Post-award**

After the EFA and the contractor come to an agreement the contract is turned over to the ROICC to administer by using a modification to give the ROICC office contracting authority. The contract time does not start until 15 days after the award, to allow the contractor to get organized.

Usually submittals will start coming into the ROICC office for review and approval soon after the award. At this point the AROICC must start using the preliminary PERT schedule to track all the submittals and their deadlines. Since the schedule has it all summarized, checking to see if the contractor has submitted appropriate documents on time is as easy as checking the dates on the schedule versus what the AROICC has received to date. The schedule makes it much easier to keep track of multiple submittals.

### ***a. Preconstruction Meeting***

Within 10 days of the award the contractor is required to contact the AROICC to schedule a preconstruction meeting. This meeting is where the planning of the project design should occur. After the design is completed another preconstruction meeting will be held to plan the actual construction. The AROICC already has a good understanding of the project requirements from using the model to develop a preliminary network schedule; so now it is time to get the contractor's input on how the project should be built. It is usually best to leave the AROICC's network schedule at the office to prevent the contractor from misunderstanding it. If the contractor sees a schedule already made by the AROICC, he may think he is required to follow the AROICC's procedure. The government is buying the



contractor's expertise to design and build the gate project, so the AROICC should listen to his ideas.

The AROICC should still run the meeting and discuss general details first and answer general questions. In the next part of the meeting, the key players should start a new network schedule together and step-by-step plan how the project design is going to be completed. There may be some resistance to taking the time to develop a network schedule at this time. But the time spent is well worth it. It is a productive way to get all of the players thinking alike and understanding each other's duties and problems. It helps build a positive attitude rather than a suspicious one. Once a network of tasks and their order of completion is agreed upon, the contractor and the government should create their own schedules. Hopefully both the government and the contractor will generate very similar schedules. They will be slightly different since the ROICC's schedule may include inter office deadlines and the contractor's may include resources and costs. After the preconstruction meeting and developing the schedule, work on the project is ready to proceed.

### **3. Design**

During the design phase the contractor is responsible for most of the work, whether it is done by in-house engineers or a subcontracted Engineer and Architect firm. The schedule for this phase (Appendix B page 70) reflects this. As the schedule shows from the "begin design" task to the final ROICC review, the only time the Government gets involved is for the 35% and 100% reviews. As previously explained these are meetings with the contractor to review the design and the contractor's progress. On the schedule only the major milestones are shown with their start and finish dates. The developed schedule with the actual

award dates and planned durations will assist the AROICC and the engineering technician in tracking the contractor's progress. Since all the information is summarized on one sheet, it is easy to check and see where the contractor should be in the project on any given date. The schedule is only a tool though, and the AROICC must be sure to check the contractor's actual progress and compare it to the plan. After checking the progress the AROICC is responsible for holding the contractor accountable for these dates. The schedule cannot replace good management skills.

During the design phase, submittals will continue to be sent to the AROICC for approval. The schedule will help identify which ones are required and where they impact the plan. It is also very useful to have the requirements summarized in one place, rather than constantly sifting through the contract documents to figure out what is due and when. For example, if the AROICC wanted to see what administrative requirements were due before the NTP could be given, all he or she has to do is look in the schedule (Appendix B, pages 70-71) and see what tasks are in the requirements box which is a predecessor to the NTP task box. The dates shown in the administrative task boxes are the earliest dates they could be handed in. They are not late until the NTP date approaches, which in this example is 14 Dec 94.

As the design and time progresses the schedule shows when the 35% review is due and helps let the AROICC know when to schedule the meeting. In this example this date should be 21 Oct 94, which is 15 days after the contract time started. The AROICC should bring the preliminary schedule to this meeting. The schedule should be reviewed with the contractor to determine if the 100% design completion date is reasonable. After this meeting, and reviewing the plans, the AROICC should have a general ideal of what the design is going

to look like. He or she can now start changing the schedule to reflect actual construction. The summary tasks can now be checked to see if all of the necessary summary tasks are included, and the order of these tasks should be checked. Since the design is still far from final, it is not a good idea to spend too much time revising the construction portion of the schedule until the 100% design submittal has been submitted. The AROICC should continue to monitor the contract schedule for the rest of the design phase and take action to keep the contractor progressing on time if necessary.

#### **4. Construction**

As shown in Appendix B, page 70, when the 100% design submittal is due, a meeting is scheduled to review the design and specifications. If the design is good and reflects what the government wants, the contractor will be given the NTP. Usually revisions are still necessary, so they are given seven days to revise and submit copies of the final plans and specifications. Once the NTP is given the contractor has 10 days to schedule the second preconstruction meeting with the AROICC and the government personnel. While the AROICC waits for the contractor to prepare for this meeting, this is the time to update the preliminary Gantt chart and calculate the PERT network to reflect the anticipated construction using the developed design. These revisions will be time consuming and must be done in detail.

##### ***a. Expanding the Schedule Summary Tasks***

The AROICC by now should be fully familiar with the plans and specifications and be able to check to make sure all the necessary summary tasks are included in the PERT chart. There will probably be several to add, since the plans will have every detail of

construction. An example is a cabinet and woodworking summary task. This is not included in the model, but it is part of the guard shack construction. Once all the summary tasks are included and placed in a logical order, it is time to expand them. This will take some time. Each summary task must be expanded into all the individual tasks that make up that portion of the project. For example, in the gate project (Appendix B, page 73) the rough carpentry summary task is split up into framing, walls, and roofing. It is important to note that this is the time to decide what level of detail will be included in the network. It is not necessary to break the summary tasks into every minute detail. It is not necessary to show every nail that is driven into every single board. This would cause the administration of the network to take far too much time, since each task in the network should be checked. Each summary task in the network should be expanded into a logical sequence of events which comprise it, so the AROICC and the engineering technician can follow the progression of work easily. A good example of this is the asphalt paving (Appendix B, page 73). It is split into four very simple tasks which make up the entire activity-placing subsurface material, spreading slurry, curing and finishing. This example is complete yet not complicated by too many tasks. The number of tasks will be based on engineering judgement.

***b. Task Categories and Dependencies***

As explained in Chapter II, this is also the time to determine whether each task is fixed or effort based, and what timing each category is assigned. Most tasks in construction are in the ASAP category but a few are assigned to other categories. In this gate example, the only other category used is the As Late As Possible category for the landscaping, since the construction vehicles would destroy it if it was done too early. The assignment of these

categories should be carefully thought out using engineering judgement.

After the tasks have been expanded and categories have been assigned, it is time to review and modify the dependencies or create new relationships. As mentioned previously, the available relationships are finish-to-start, start-to-start, start-to-finish, and finish-to-finish.

The finish-to-start is the most common and is the constraint or relationship the computer automatically assigns to the dependency. An example is shown in Figure 5; the concrete must be poured before curing can begin. The start-to-start is shown in Figure 6.

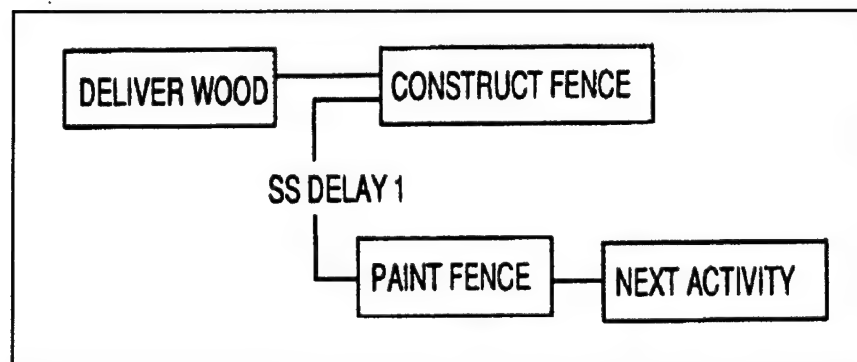


Figure 6. Start-to-Start

This constraint allows the successor to start one day after the predecessor has started. This is common sense, there is no reason the fence must be finished before painting can begin. The next constraint is the start-to-finish as shown in Figure 7. This constraint is not often used. A good example is a site that used its own power generator until the main electricity connection has been made. Operating the generator cannot be finished before the electrical connection has been made. Another constraint is the finish-to-finish as shown in Figure 8. This constraint forces the successor to finish after the predecessor has finished, but allows it

to start some time after the predecessor has started (Sanders, 1991). These relationships can not be seen in Appendix B unless the dates are studied carefully. For example, the pouring of concrete tasks are all interconnected within the program using a start-to-start relationship.

Establishing dependencies takes time and engineering judgement, and it is

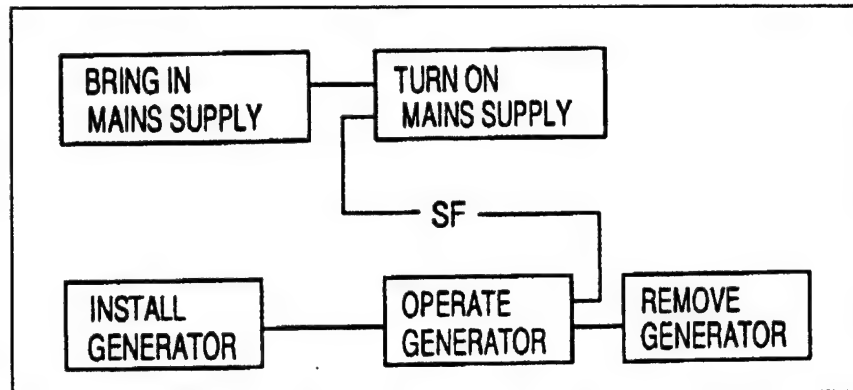


Figure 7. Start-to-Finish

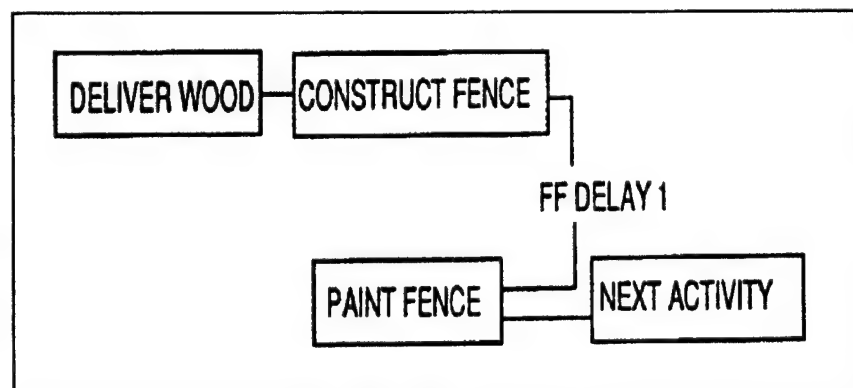


Figure 8. Finish-to-Finish

important to realize it is almost impossible to get it perfect the first time. Once the tasks are interconnected it is important to move the tasks around so as few activity arrows cross as possible. This will make it easier to move through the network task by task. A common

error which should be avoided is loops in activity arrows. Any given task should have a clear predecessor and successor, and they should not be the same task. Once the AROICC and the technical representative are satisfied with the network it is time to calculate dates.

*c. Calculating the Critical Path and Float*

In the early days of CPM, calculating dates would often take several days, but Timeline can now do it in seconds. Once the computer has calculated dates it is easy to find errors, but it can be time consuming. In the network there will now be several different paths to follow to the completion date. The longest path is the critical path. In Appendix B the critical path starts with the design sequence of tasks, goes through the notice to proceed and the concrete work. After the concrete work it goes through rough carpentry, mechanical systems, electrical, finish carpentry, lath and plaster, paint, landscaping and finish project. The critical path is the path where no delays can occur without impacting the estimated completion date.

The other shorter paths will now have extra time to finish their tasks. This extra time is called float or slack. Positive float indicates there is “breathing room” between the time that all the tasks are projected to be completed and the completion of the project. For example, in Appendix B, pages 71-72, after the NTP the contractor will be doing excavation on the critical path. The ROICC must be notified prior to the excavation to check for underground utilities. The NTP is shown to be 14 Dec 94, but excavation doesn’t begin until 11 Jan 95. The notification and approval has a duration of one day; so its start date is shown as 14 Dec 94. This period from the 14 Dec 94 to 11 Jan 95 is called the float. If the notification happens on 30 Dec 94 it will not delay the project. Float is an extremely

important concept to understand.

After all the tasks, durations, relationships, and dependencies have been inputted, it is time to run the calculation. The Timeline program on command will calculate all the start and completion dates for all the tasks in the network. The final result is the project completion date as shown in Appendix B, page 76. It is important to remember the network will not be perfect the first time. It usually takes several iterations of modifications and recalculations before the schedule is realistic and correct. Once the AROICC is satisfied with the schedule, he or she is ready for the preconstruction meeting.

*d. Preconstruction Meeting*

The preconstruction meeting should be split into two parts. The first should be set aside to discuss general issues on the site, such as gate passes, safety requirements and general scheduling issues. This should be attended by all interested personnel, including the customer. The next part should involve the AROICC, engineering representative and contracting personnel, who should sit down and plan a network schedule for the construction phase. This will take a lot of time and probably will not be very popular at first, but, once the group realizes they are working together and sharing ideas, it will get easier. By planning the project with all the key personnel, issues and problems can be worked out early before the contract is delayed.

Hopefully by now the contractor has developed and submitted his own acceptable CPM schedule and the AROICC can now modify his or hers with the information from the preconstruction meeting. Using the schedule the AROICC should ensure all required submittals have been approved before on site construction begins.



*e. Actual Construction*

When construction begins, most of the problems and delays occur in the first half of construction. By planning ahead, using a network and analyzing processes, hopefully some problems have already been avoided.

Daily monitoring of the construction is done by the engineering technician; so he or she should be comfortable using the network to identify what tasks are to be completed on any given day. The AROICC will monitor the contract progress using the schedule and be able to judge when a problem is developing. The AROICC will then be able judge when to get personally involved in the project to assist the contractor. By early identification of the problem, it can be solved before the whole project is impacted. The schedule will change every day; so it will need to be updated periodically to see how the completion date is impacted. Every two weeks is usually often enough for updates. More frequent updates would make the time spent on the computer excessive.

The schedule will be a valuable tool when changes occur. Usually the contractor will automatically request additional time to complete the changes. By analyzing whether the changes will impact the critical path, the government will be able to determine whether the contract will actually be delayed. For example, if during excavation a rainstorm washed out all work done in two days and it had to be redone, the contractor would request a two day extension for the entire project to redo the work. The AROICC can look at the schedule and see if excavation is on the critical path. If it is, the two day extension should be granted. If not the contractor is not entitled to more time. The schedule objectively shows everyone how the change or delay actually impacts the project.

## **5. Summary**

Implementing the model to create a network schedule for a construction project takes time but it is very valuable to the successful administration of the project. Using the program is very simple and the model already has the basics of a government contract inputted in a database. By using the model the AROICC can save hours of tedious inputting of government contract requirements. The rest of the schedule is developed using the design which requires engineering knowledge.

Once the project is started, the network will change often during construction. The AROICC and technical representative will need to monitor the contract to determine whether the contractor is on schedule. The network gives the AROICC a summary of the entire project at a glance and saves a great deal of time, since he or she is not constantly trying to find the requirements in the contract documents and manage every task in the construction process. It must be remembered that the schedule is only a tool; good engineering judgement and sound management skills must be used also for the successful implementation of a project.



## **IV. COST/BENEFIT STUDY**

### **A. DEFINITIONS AND PUBLICATIONS**

A cost/benefit study is “a systematic approach to the problem of choosing how to employ scarce resources to achieve a given objective(s) in an effective and efficient manner” (NAVFAC P422, 1993). The cost/benefit study is a tool to study the factors affecting a decision and assist in the actual decision making process. This study forces the decision maker to focus on the economic aspects of a decision and documents the thought process used to reach the decision (NAVFAC P422, 1993). It is a systematic way to organize the costs and benefits of the various alternatives being studied, compare costs and benefits, rank alternatives, and perform a sensitivity analysis.

Within the executive branch of the government, the Office of Management and Budget (OMB) publishes Circular No. A-94 dated 29 October 1992. This circular “provides guidance on cost-benefit, cost-effectiveness, and lease-purchase analysis to be used by agencies in evaluating Federal activities” (OMB Circular A-94, 1992). This circular is designed to give the reader general guidance on discount rates, the measurement of costs and benefits, the treatment of uncertainty, and other issues used in analyses submitted to OMB in support of legislative and budget programs (OMB Circular A-94, 1992). Since the circular does not give specific steps to help a reader prepare a cost/benefit analysis, most agencies have developed their own specific guidelines. For example, the Naval Facilities Engineering Command has developed the Economic Analysis Handbook, NAVFAC P-422, which gives all preparers of cost/benefit analyses within NAVFAC step-by-step guidance. This handbook

is also available for purchase by other agencies within the government that may not have their own established methods. The handbook gives a very detailed explanation of the six steps in developing a cost/benefit analysis. This explanation is simple, and uses many examples to illustrate methods and concepts.

This thesis will use the general guidelines from the OMB Circular A-94 to formulate the concepts and theories of the cost/benefit study, and the specific step-by-step instructions from the NAVFAC P-422 to organize the study. The lack of data available at this time will not allow a thorough cost/benefit analysis to be performed. As a result this study will be limited to analyzing very basic costs and benefits and discussing them. Later as the CPM method is actually used on projects, an analytical study can be performed.

## **B. PURPOSE OF COST/BENEFIT ANALYSIS**

As stated in NAVFAC P-422, there are three main reasons to perform a cost/benefit analysis when considering alternatives in a decision making process: to maximize the use of available resources, to ensure qualitative values are considered, and to implement DOD and NAVFAC policy. In today's cost cutting atmosphere it is imperative that government employees completely examine all alternatives to ensure available resources are maximized when making decisions involving complex issues and high cost construction. When making a decision, quantitative values are defined and qualitative factors are considered to document all costs and benefits, compare and rank alternatives, and test the uncertainties. Without these factors an analysis would be incomplete. The cost/benefit analysis is important to the planning, programming and budgeting process at all levels of the government; and it provides an evaluation and documentation process. Cost/benefit analyses are valuable decision making

tools when used properly.

### **C. STUDY OF COSTS AND BENEFITS**

As previously mentioned, this thesis will follow the six step procedure for economic analysis outlined in NAVFAC P-422 with one exception. Since very little of this analysis will be numerical, two steps will be combined. The five steps will be (1) defining the objective, (2) generating alternatives, (3) formulating assumptions and constraints, (4) determining and comparing costs and benefits, and ranking alternatives, and (5) performing a sensitivity analysis.

The main gate construction contract for the Naval Postgraduate School will be used as an example to illustrate some of the costs and benefits of the two management alternatives being studied, manual methods and computerized CPM.

#### **1. Define the Objective**

There is a desperate need within the CEC to develop better project management techniques. Proactive management is much more effective than the current reactive management. This objective of this analysis is to investigate the costs and benefits of the two methods of project management introduced in the previous section, and determine if the new critical path method is the most efficient and economical method for controlling construction projects.

#### **2. Identify Alternatives**

Only two contract management methods will be examined in this section. The current method of administration and control of contracts is a manual tracking and filing system with computer support for word processing functions. The proposed method uses computerized

critical path management techniques to formulate a network schedule to track and control all the tasks which make up a project. A model has been developed which has all the typical government requirements already inputted into a network, so all a manager has to do is add the unique project tasks to develop a complete network schedule.

### **3. Formulate Assumptions and Identify Constraints**

To continue with this analysis, some assumptions regarding the environment must be made. First it is assumed project managers in the Civil Engineer Corps will be the users of the methods discussed. Each of these project managers is assumed to have an engineering degree with some basic project management experience or education. It is also assumed that the users have some experience using computer software and hardware. Most offices have personal computers, so it is assumed the ROICC offices have personal computers with 486 processors and printers for the AROICC's. Also, it is assumed the number of personnel working in the office will not change and the number of contracts being administered will remain constant.

There are several constraints which must be considered. Cost is the biggest constraint. ROICC offices have very limited funding, so expensive tools are not feasible. This analysis is limited to very low cost alternatives. This analysis is also constrained by cost since it will be impossible to accurately determine the actual costs of the alternatives. Time is another constraint which must be mentioned. A contract is awarded with a specific amount of time to complete the contract requirements. The alternatives must allow the contract to be completed as quickly as possible and within the required time. Also, the alternatives cannot be training-intensive, since it is impossible for a project manager to be away for any

length of time to learn a new system. It is impossible at this point to estimate exactly how many man-hours are needed for administering the contracts using either method.

#### **4. Costs and Benefits**

There are two types of costs and benefits: quantifiable and nonquantifiable. For this example there is very little that can actually be quantified. The documentation for the current method is limited so that actual costs will not be able to be determined accurately. Also, since the developed CPM model has never been used, there is no way to accurately forecast the actual costs. Most of the costs and benefits analyzed here will be nonquantifiable and will be discussed and compared.

##### ***a. Costs***

The costs of the current method of contract administration are estimated to be between 2 percent and 5 percent of the contract cost (O'Brien, 1993). Since the gate project is valued at \$183,000 the estimated contract administrative costs are between \$3660 and \$9150. The estimated cost of administering a contract using the CPM method is 0.5 percent of the contract cost. So, for the gate project the cost would be approximately \$915 (O'Brien, 1993). To use the CPM method a project management software program must be purchased. A simple program called Timeline by Symantec was used to develop the model. Most programs cost \$300-\$600. Since Timeline does require some training, an outside consultant can be hired to train personnel for approximately \$500 per day. Most training sessions are only 1-3 days.

The difference between the cost of administration of the more expensive current method, and the CPM method is between \$2745 and \$8235. With procurement of



a \$600 package of software, and three days of training added to the administration of the contract, CPM is estimated to cost approximately \$3015. Using CPM is less expensive than the estimated minimum cost of the current method, and using the model repeatedly decreases this cost even further.

There are numerous costs of using both methods which cannot be estimated numerically. The most important cost using the current method is the high cost of change orders which have become very common in construction contracts. Contractors bid or negotiate a price that is too low to cover the actual construction costs to ensure they are awarded the contract. They then have to find problems with the design to negotiate for changes. A change order takes time to negotiate and settle; so, in order to avoid long costly delays, the government may settle for too high a price.

Time is another significant source of costs. It is not uncommon for construction contracts using the current method to take twice the time originally specified in the awarded contract. The costs involved in time delays include labor and overhead. For every day the contract is delayed the government pays for personnel to continue administering the contract. Overhead includes many costs, such as the transportation costs for the field personnel to get to the construction site, plus their daily salaries. The government also loses the use of the new facility. The gate contract actually took 250 days, which is 75 days over the specified contract time of 175 days. The delays began with the contractor's problems with the design subcontractor's lack of performance. The contractor did not hold the subcontractor accountable for a complete design on time, and the government did not hold the prime contractor to the deadlines. Another source of delays occurred during construction;

the contractor found several scope and design discrepancies. These resulted in various change orders which had to be developed, negotiated and signed. As a result of the lost time, the contractor often rushes to finish the project; so the quality of construction is a cost factor. Poor quality construction must be replaced sooner than high quality construction. Often the materials are not ordered on time, arrive late, or arrive in poor condition but are used anyway.

General costs of using the CPM method also involve time costs, but they are different from the current method time costs. CPM time costs occur mostly during start up. The program does take time to learn how to use. However, most engineers are proficient after using it for one project. When inputting activities and tasks of a project, the average person can input approximately 300 tasks per hour (O'Brien, 1993). It is estimated that 70 percent of the contract administration time is spent during the preconstruction phase in planning and developing a schedule when using CPM (Ahuja, 1994). Once the project schedule has been developed with the contractor and work begins, the AROICC doesn't need to be involved on a daily basis until there are problems to solve. It has been proven that by using CPM scheduling, contract duration can be decreased overall by 20-50 percent (O'Brien, 1993). In government contracting, time is equal to money. Planning a project initially with the contractor using CPM significantly decreases the costs overall.

Another cost of the current method of contract administration is the toll it takes on the people trying to administer the contract. The lack of organization and control makes the contract much more complicated and difficult to administer. The AROICC gets overwhelmed and frustrated with trying to keep up with all aspects of the project. This results in lost productivity, poor morale, and poor retention of CEC officers and other

government personnel.

The CPM method may also have an initial impact on morale. AROICC's and other government personnel have been using the current method for so long that a new method may decrease morale initially. There will also be an initial constant involvement of the ROICC in the use of this method to ensure the project management staff is actually using the method properly.

There are many nonquantitative costs for both methods. The current method has significant costs since change orders, time delays, inferior quality and poor morale have become the "norm" in government contracting. The initial start-up cost of the CPM method is significant, but compared to the costs of numerous change orders, lengthy delays, and replacing inferior work it is minor. As previously mentioned, the morale may decrease at first with CPM. It can be difficult to learn a new program and new ways to administer a contract, but, as government employees and contractors see how much easier it gets with experience, morale will improve. Many people involved with government contracting are already frustrated and see no way out, so CPM may provide hope for better project management. It is better to have the possibility of improving the contracting process than standing by and doing nothing.

***b. Benefits***

There are no quantifiable benefits of using the current method. The only quantifiable benefit of using the CPM method is the savings of administrative costs. As shown earlier the current method costs between \$3660 and \$9150, and the CPM method is estimated to cost only \$915. Even with training costs and procurement costs of the software the CPM

method is still less expensive.

The nonquantifiable benefits of using the current method involve personnel. Government employees and contractors are comfortable with the current method of administration. They know what to expect from each other and have developed routine ways of doing business. CPM is unfamiliar and takes time to learn, so there will be some initial resistance.

The nonquantifiable benefits of CPM are numerous. The most obvious benefit is the whole project becomes a logical sequence of events which can easily be tracked and used as a tool to effectively control the project. By increasing control, the government saves valuable resources, and time, while improving quality.

The benefits for the AROICC begin with the award of the contract. Using this method the AROICC must use the contract documents and the CPM model to develop a preliminary network schedule. The model significantly decreases the time to input tasks, since all the standard contract requirements are already inputted into a sample network. Developing a schedule forces early planning. Early planning has several benefits, including, but not limited to, early identification of design problems, complete knowledge of the project, and increased confidence. During the preconstruction meeting, developing a network plan with the contractor forces the government and the contractor to focus on an objective and to work as a team in planning the construction of the project. Actual methods and sequences are discussed and agreed upon, contract requirements are reviewed, and a realistic schedule is generated. Having an early schedule gives the contractor an idea of when materials will be needed, so that long lead items can be ordered early. Reviewing the design with the

contractor early will help identify design and construction problems before construction is delayed. An added benefit of using the preconstruction meeting as a planning meeting is that the contractor sees the government is interested in the project, and is ready work as a team with the contractor. The current method has no planning guidelines beyond discussing the basic requirements at a preconstruction meeting, and usually only a bar chart schedule is required. This schedule is rarely used. Problems are dealt with as they arise with change orders which cause expensive delays.

Once the schedule is generated and construction begins, there are other benefits of using the CPM model to develop a plan. The task-by-task network schedule is completely factual and is not easy to manipulate. It shows a firm start date and a completion date. When problems do occur the government and the contractor can use the schedule to objectively discuss the actual impact of the problem on the project. This eliminates personality conflicts, excuses and rationalizations.

The better communications and coordination from using the CPM method have many benefits. The project doesn't have as many time delays from poor planning, the quality of work is improved, and the cost of changes is reduced. Change orders are much easier with the CPM network schedule. When negotiating the scope of changes with the contractor, it can be used to objectively map out how the changes will impact construction and assist with planning the best method to implement them with the least impact on the project. This eliminates personality conflicts. The current method of administering change orders is to negotiate a price and give an automatic time extension for the additional work. The government usually doesn't check to see if this change is on the critical path and will

actually delay construction. An added benefit of better government management will attract better quality contractors who don't need change orders to finish on time with a profit. Claims will also be reduced if the contractor is satisfied with the government's management of change orders. Claims are often made for higher amounts than the contract is worth, since the contractor's overhead is approximately 25 percent of the contract cost. Claims generally are submitted when the contractor is past the contract completion date and over budget. If the CPM method reduces the time spent on a project, it is logical to assume disputes and claims will occur less often.

The CPM network is based on common sense and is very easy to read. Even an uneducated laborer can read the tasks, follow the activity arrows, and suggest better ways of completing a particular activity. Out in the field the schedule is easy to post up on a board for daily reference, and it provides a way to track and mark progress. The schedule is dynamic, but it gives personnel an accurate visual idea of where they are in the construction process and provides a "red light" when a task is late in starting or if a problem is developing. For example, in the gate project there were problems getting the final design on time. If a network schedule had been used it would have been immediately apparent that the date on the schedule had come and gone, and the AROICC could have taken measures to correct the problem early. Also, being able to see the whole project picture, track the progression, and make improvement suggestions, boost morale for any worker.

The schedule is very easy to revise as the project progresses. The computer does all the hard work. All the project manager has to do is input the revised dates or durations, and the computer will recalculate a new schedule in seconds. Updating the

schedule also emphasizes the passage of time.

A very important benefit of the CPM method is that it reduces the amount of time the AROICC needs to spend on each particular contract. With a CPM network schedule the engineering technician, who inspects the site daily, can keep the AROICC informed and up to date on what tasks have been completed. The AROICC can analyze the network for potential problems and get involved early to prevent delays. This way the AROICC does not need to be involved in every day tasks when the project is running smoothly. This saves the AROICC a great deal of time. Using the current method, the AROICC is involved with every task when he or she has the time. This necessitates many site visits. The CPM method will reduce frustration and improve morale. The CPM schedule also shows the contractor the government is interested in the progression of the project and keeps both parties aware of time passing.

The CPM network also makes it easier to report progress to the customer and higher authority. The schedule is easy to print out, and is easy to understand since the network schedule is a visual tool. The schedule is objective so one can see exactly how much work has actually been completed. The current method relies on meetings and the AROICC's perception of where construction is. Using the CPM method, payments to the contractor are easy to verify and approve for the same reason; because it is possible to see exactly where he stands in the project schedule. The CPM schedule is objective.

After the CPM method is implemented, each completed project will be a historical file on actual costs and task durations. These historical files can be used to create better specifications and designs.

Overall, the CPM method with the CPM model has many benefits as compared with the current method of administration. It reduces the cost of construction and helps reduce time delays. It also increases the quality of work since the correct materials are ordered in plenty of time to use them in the project. There is less rework if the job is planned and then executed. Also, a well managed project increases employee satisfaction and facilitates positive team work with the contractor.

*c. Summary*

After determining the costs and benefits and comparing them, it is obvious the current method of contract administration is a source of waste in the government. The CPM method is the most effective of the two alternatives under the given constraints. The costs are lower and the benefits definitely outweigh the costs.

**5. Sensitivity Analysis**

Choosing between the two alternatives does have a moderate level of uncertainty when considering the estimated administrative costs. As stated earlier, the estimated cost of administering the NPS gate contract using the current method is approximately 2-5 percent of the contract cost, or \$3660-\$9150. The estimated cost of using the CPM method is 0.5 percent or \$915. This cost is even lower if the developed CPM model is used, since several hours of inputting data have already been done. Even if the CPM method cost increased by 300 percent it would still equal the low end of the current method's cost range. These figures are based on accumulated experience of engineers who have studied the costs of contract administration.(O'Brien, 1993) These figures are only estimates of course. The training costs of CPM and the purchase cost of project management software are based on quotes from



computer magazine references, so there is a very low level of uncertainty associated with them.

The nonquantifiable costs and benefits have moderate uncertainty since the problems mentioned are based on the author's personal experience and discussions with other CEC officers who have been AROICC's. All officers interviewed had the same complaint. There was too much work to do for one person. The benefits of both methods are based on common sense and have little uncertainty associated with them. Even though there is some uncertainty regarding the costs and benefits, it will not alter the ranking of the alternatives. The benefits clearly outweigh the costs for the CPM method.

#### **D. SUMMARY**

The cost/benefit study clearly shows that using the CPM method with the developed model is more beneficial to the government when compared to the current method of administration. The CPM method with project management software is inexpensive and requires minimal training so it falls within the studies stated constraints. The CPM method will reduce costs, decrease contract duration and improve the quality of construction.

## **V. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

The first research question asked if CPM is an effective, efficient, consistent method to manage and control a "typical construction contract". As explained and illustrated in the previous chapters, it is. Its benefits are numerous, but most significantly, it is a useful tool to control the schedule, reduce costs and improve quality of construction projects.

With all the project management software packages available, the CPM method is even easier to use today. All that is necessary is to input tasks into a Gantt chart, assign durations to each task, place them in order of execution, and establish interdependencies. The computer will then calculate the all the start and completion dates for each task, contract completion date, and the critical path.

The Timeline software made it easy to develop a standard model for a typical government contract. This answers the second research question. To develop the model, all the common required administrative requirements were inputted and saved, with the appropriate durations. Along with the administrative requirements, common simple construction summary tasks were also inputted and saved. As shown earlier, this model can be used as a starting point for government contracts to save the AROICC hours of inputting tasks that are common to the majority of government contracts.

The third research question asked if the CPM method is better than the current method of administration. The cost/benefit study indicated that the CPM method used with the model is much more efficient and cost effective than the current manual methods of

contract administration. As a result, this method and model will assist the AROICC, by allowing him or her to consistently manage a project and help to determine where his or her personal involvement is needed most. This saves the AROICC time, and the effective management of the contract will improve the morale of all the government workers administering the project.

In summary, the existing method of administering a contract is inadequate and very frustrating for all involved. Using CPM along with the developed model will reduce this frustration, improve quality, reduce costs and help complete the project on time.

## **B. RECOMMENDATIONS**

### **1. Implementation**

Since CPM and the developed model are an effective and efficient way to manage construction contracts it should be implemented in all ROICC offices. This could be difficult, since there are many ROICC offices. NAVFAC would have to be convinced CPM is the best method of contract administration and require it be included in all contract specifications. Each individual ROICC office has enough freedom to choose which method of administration will be used. If enough ROICC offices have success with the CPM method and model, NAVFAC will eventually notice the improvement in management and make CPM a requirement for all construction contracts.

#### ***a. Procedure***

The best way to implement the CPM method is to introduce it slowly. First, buy the program and introduce it to the AROICC's and engineering technicians, and convince them it is a superior way to administer a contract. Informal training is a good way to do this.

Next, have the AROICC's use the model to develop a network plan for their next new contract. First, the ROICC or someone else in the office should be comfortable enough with the program and methods to answer questions and offer encouragement. The plan should then be used to track and control the whole project. The ROICC will need to check the AROICC's progress to make sure the plan is used properly. Otherwise changing the methods of administration could end up being a failure. Once the AROICC and other employees become comfortable with the process, and have success with it, they will be willing to try it on other projects.

*b. Problems*

As with any new method or process, there will be difficulty in implementing it. At first there will be some resistance to trying something new. Management will probably support it in concept but have no idea of how to implement it. The AROICC and the engineering technician will feel this lack of support and participation, and assume it will take far too much time to plan a project step-by-step and develop a network schedule. The contractor's resistance to "high tech gimmicks" will reinforce this feeling. Since CPM is technically more complex than the current method, employees will be reluctant to try it. Other problems occur during the project. Even if a schedule is generated, it may not be properly used or updated. It may be produced only to fulfill a contract requirement, while the current contract administrative methods are not changed substantively. Another serious problem is that the current contract specifications do not clearly specify a network schedule. As a result, it will be difficult to get the contractor to produce one. This requirement may need to be added to the specifications at the Engineering Field Activity. The CPM schedule

requirement can also be added to the contract after award by the ROICC.

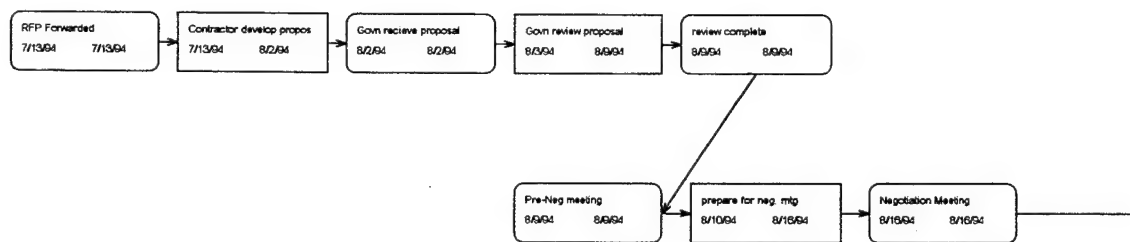
*c. Summary*

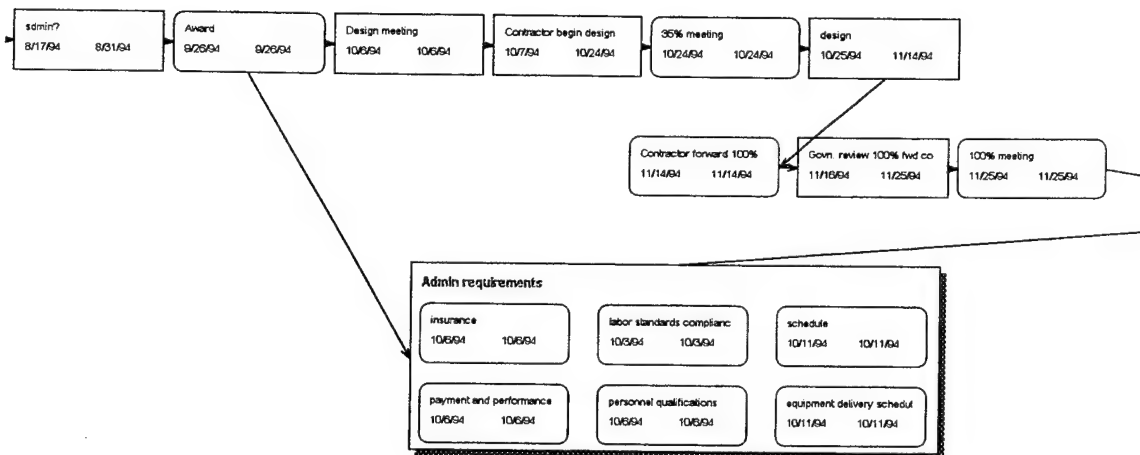
There will be problems implementing the CPM method, but persistence and patience will pay off. Once there are a few success stories to tell, people will be eager to implement CPM to manage their projects more easily and effectively.

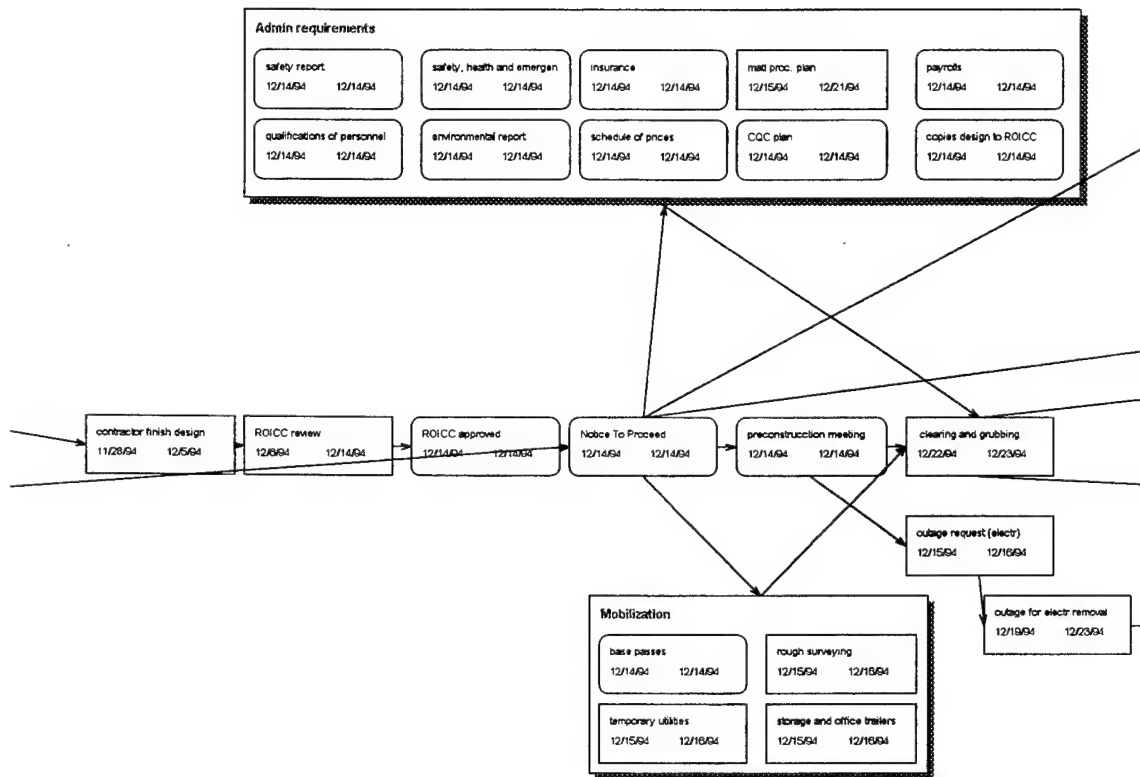
**C. Recommendation for Further Study**

This method is obviously beneficial to all personnel involved in a contract, but there is no real quantitative proof. Once this method is implemented for a few projects, an interesting thesis topic would be to analyze the actual reduction in the costs of construction and time delays. These projects could be used as actual case studies and compared to similar projects done in the past using the traditional method of administration and control.

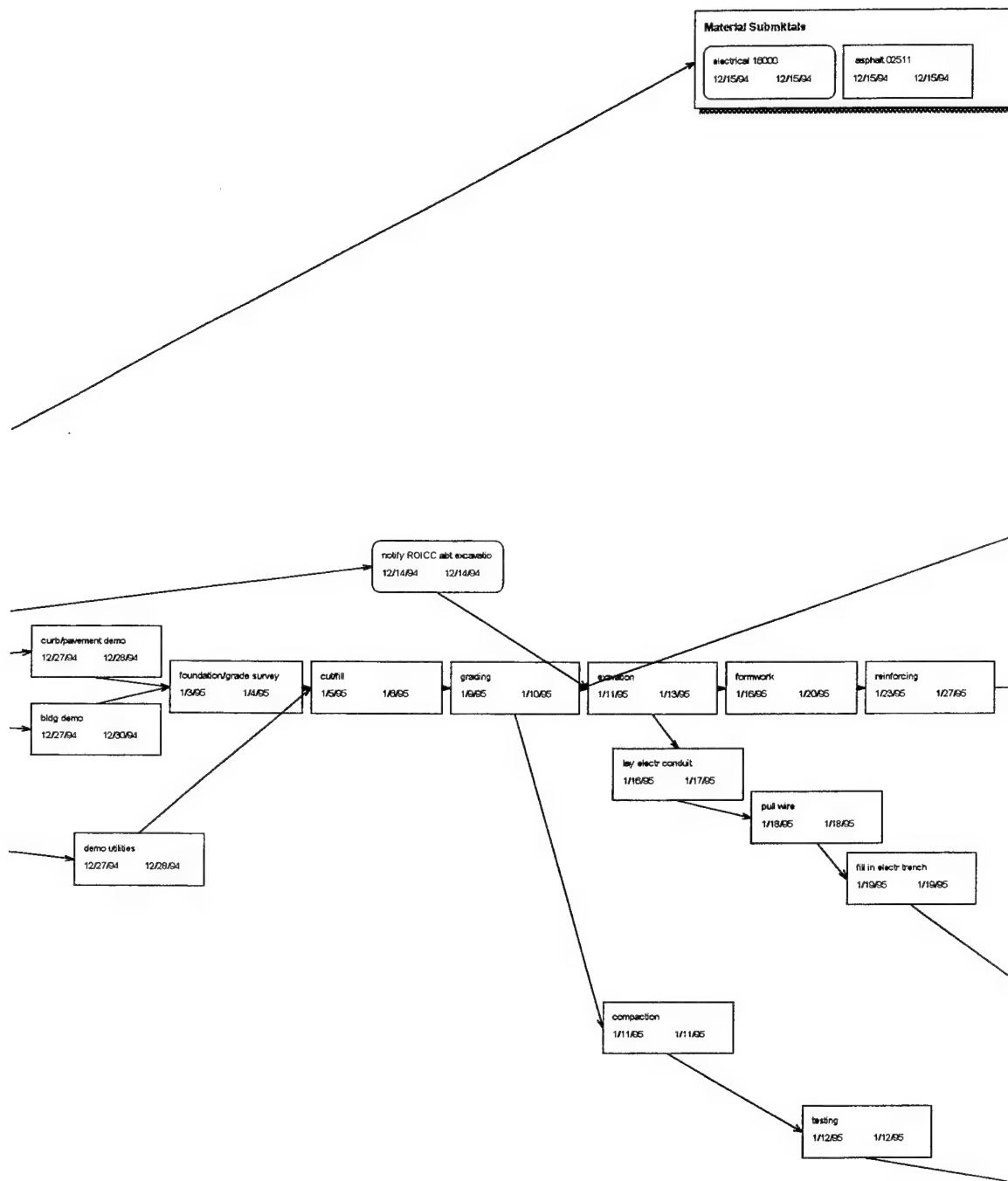
## APPENDIX A. THE CPM MODEL



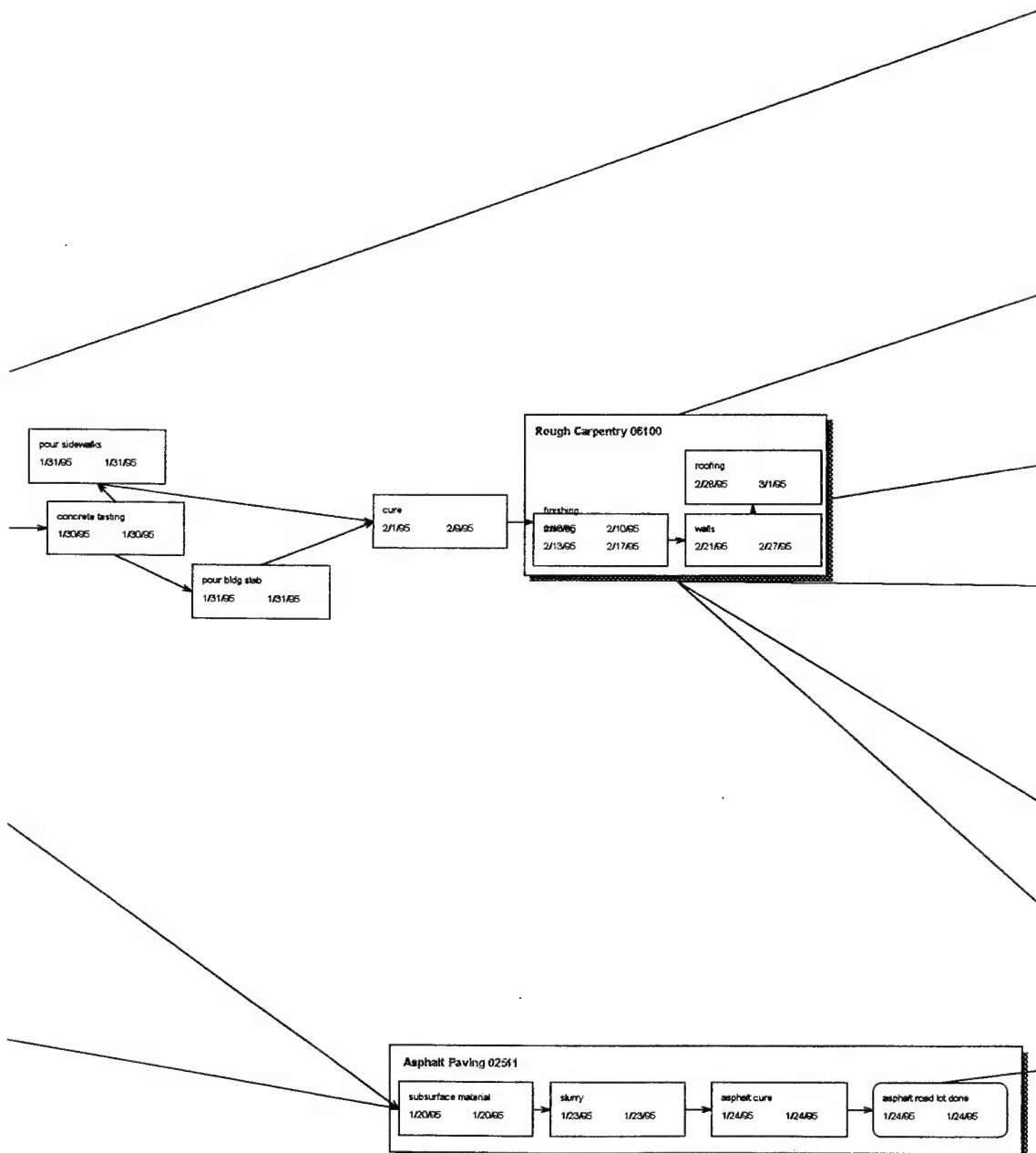


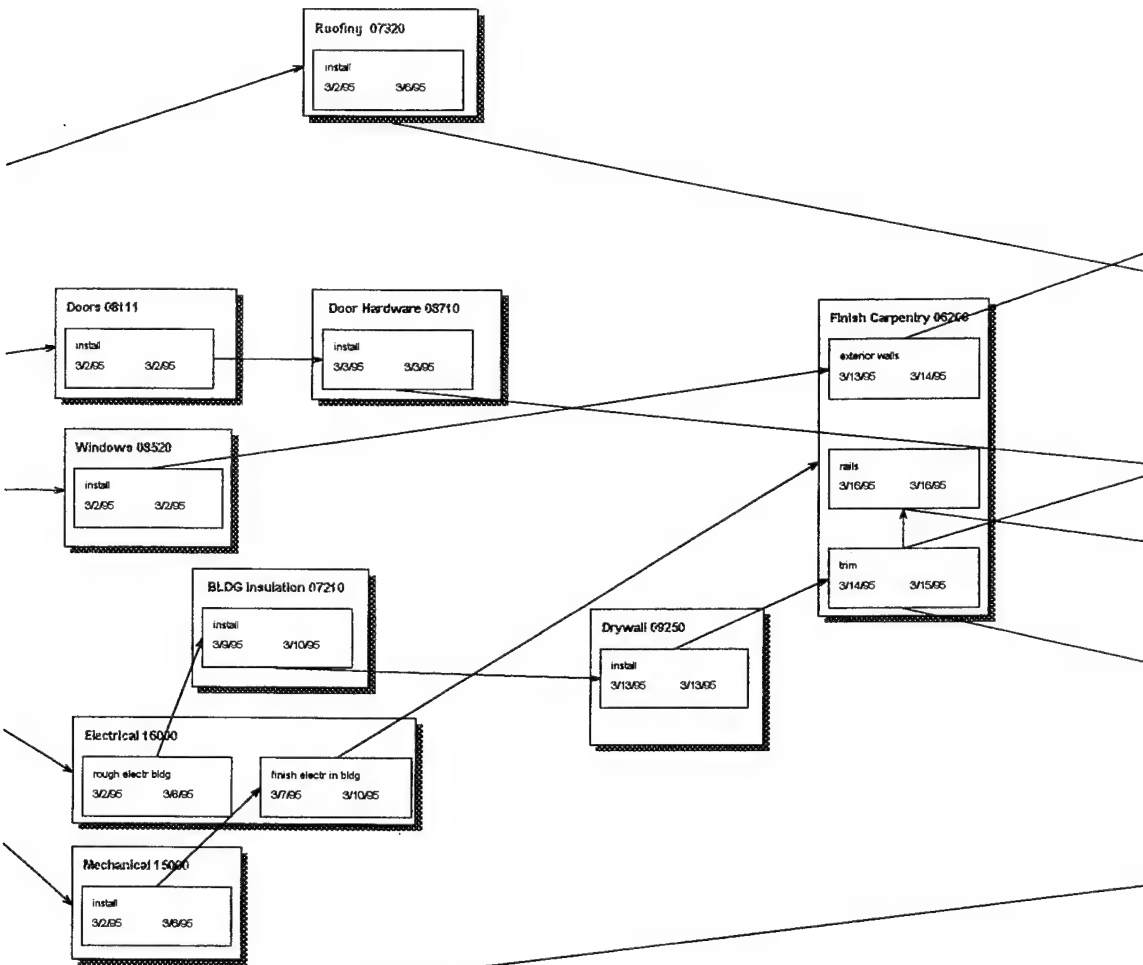
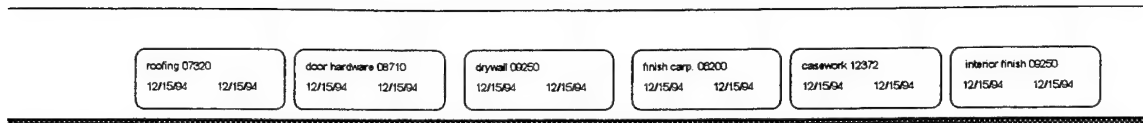




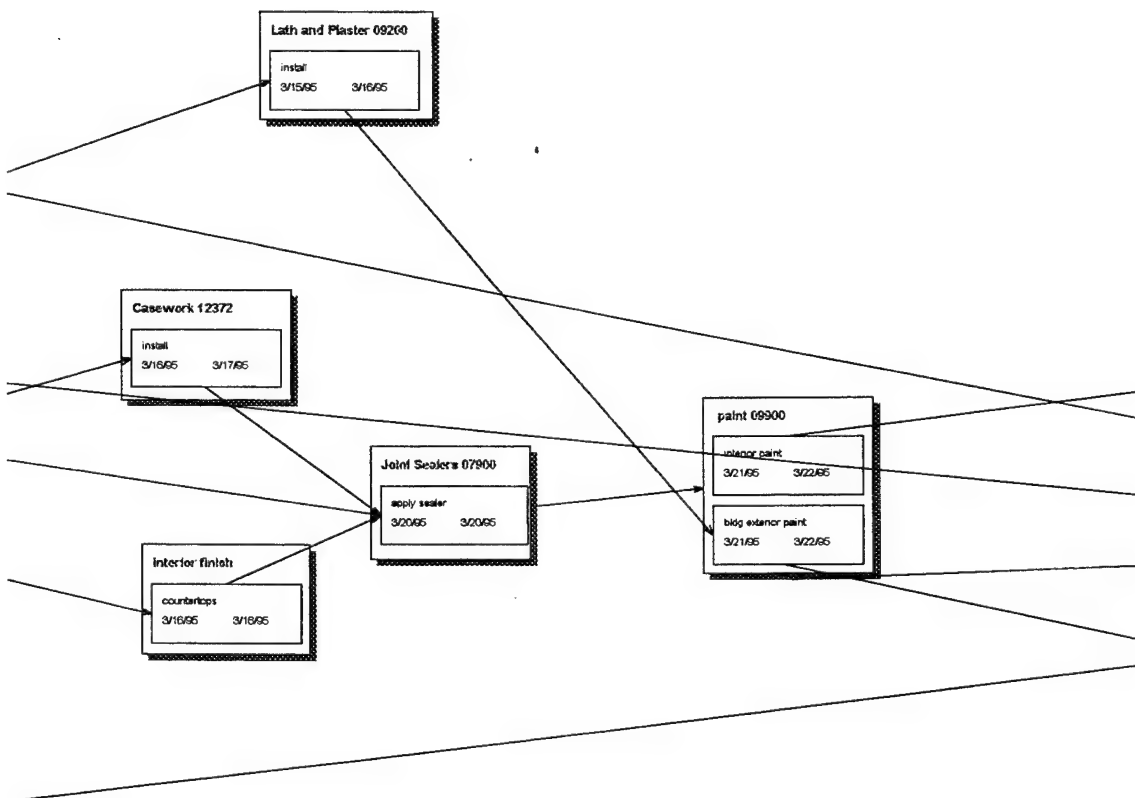


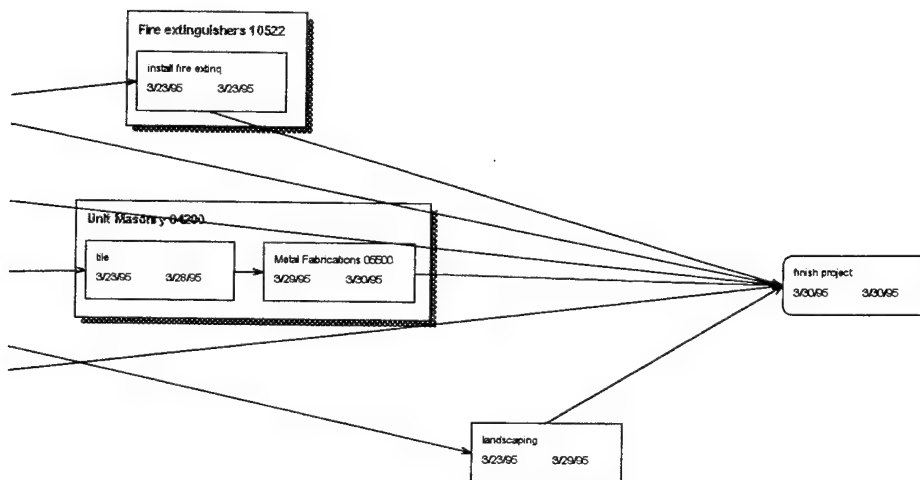
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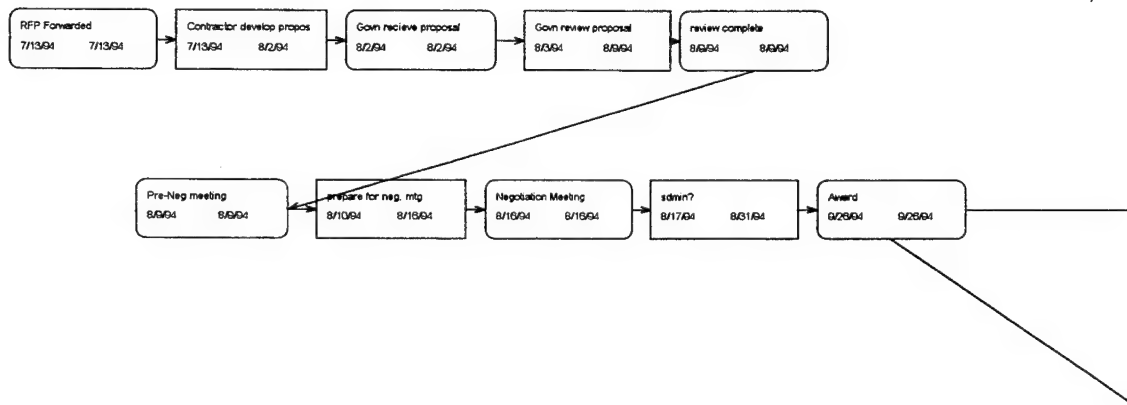


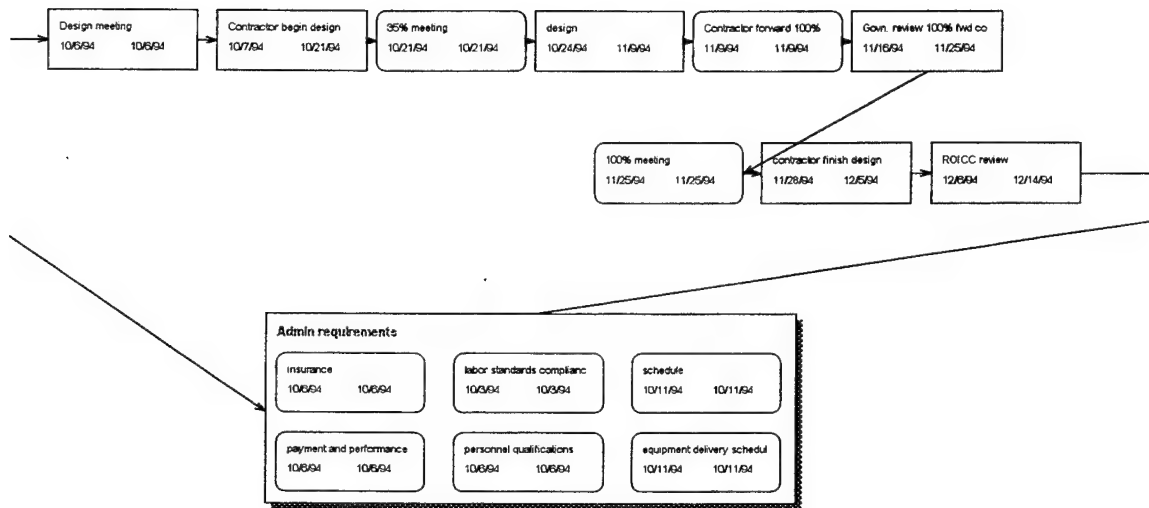
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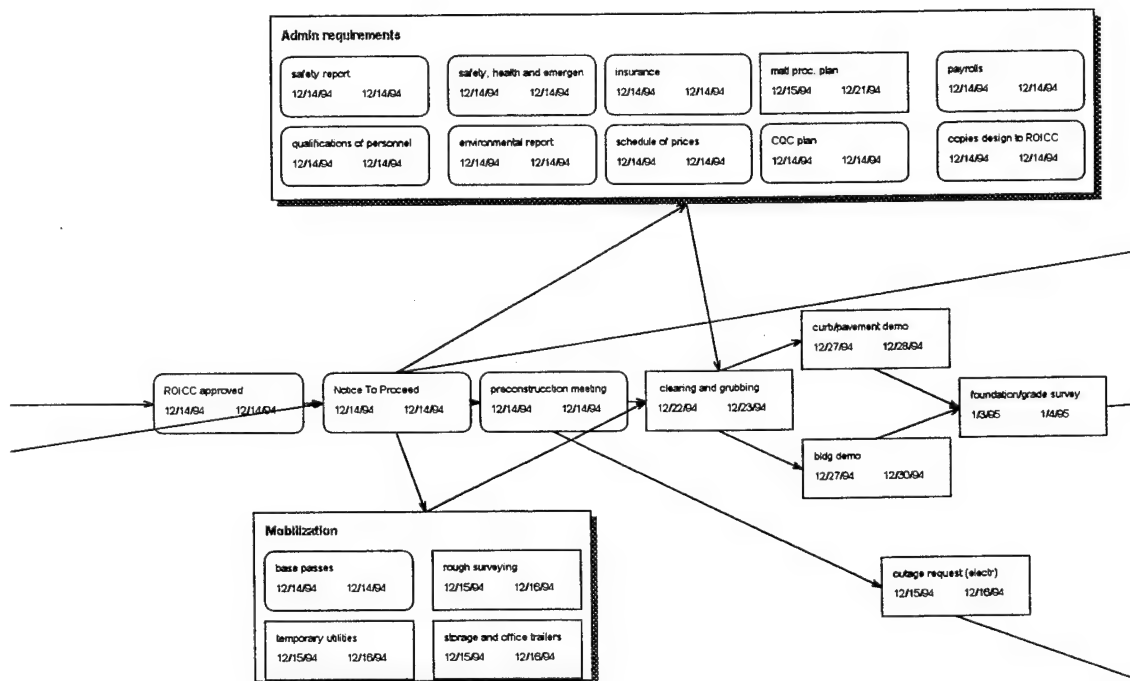




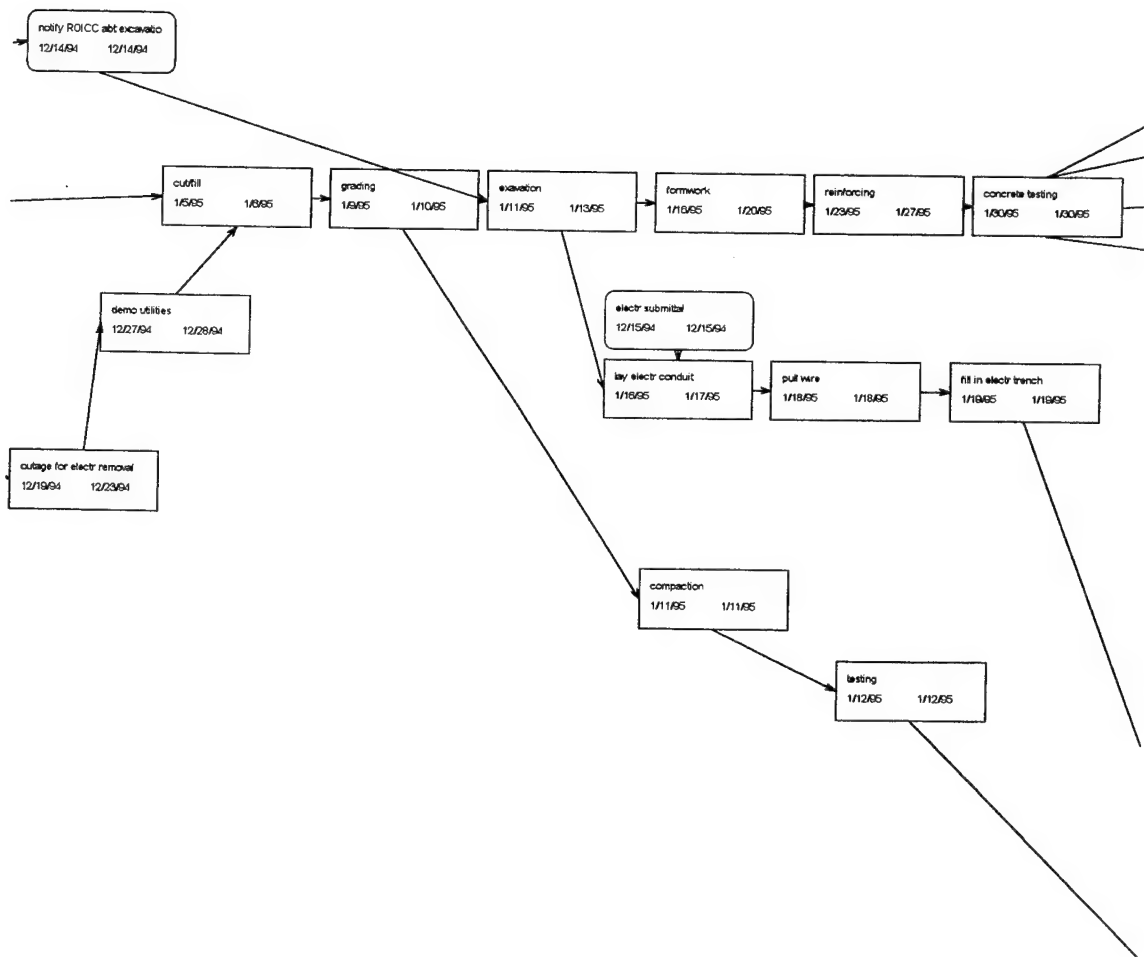
## APPENDIX B. THE NPS GATE PROJECT

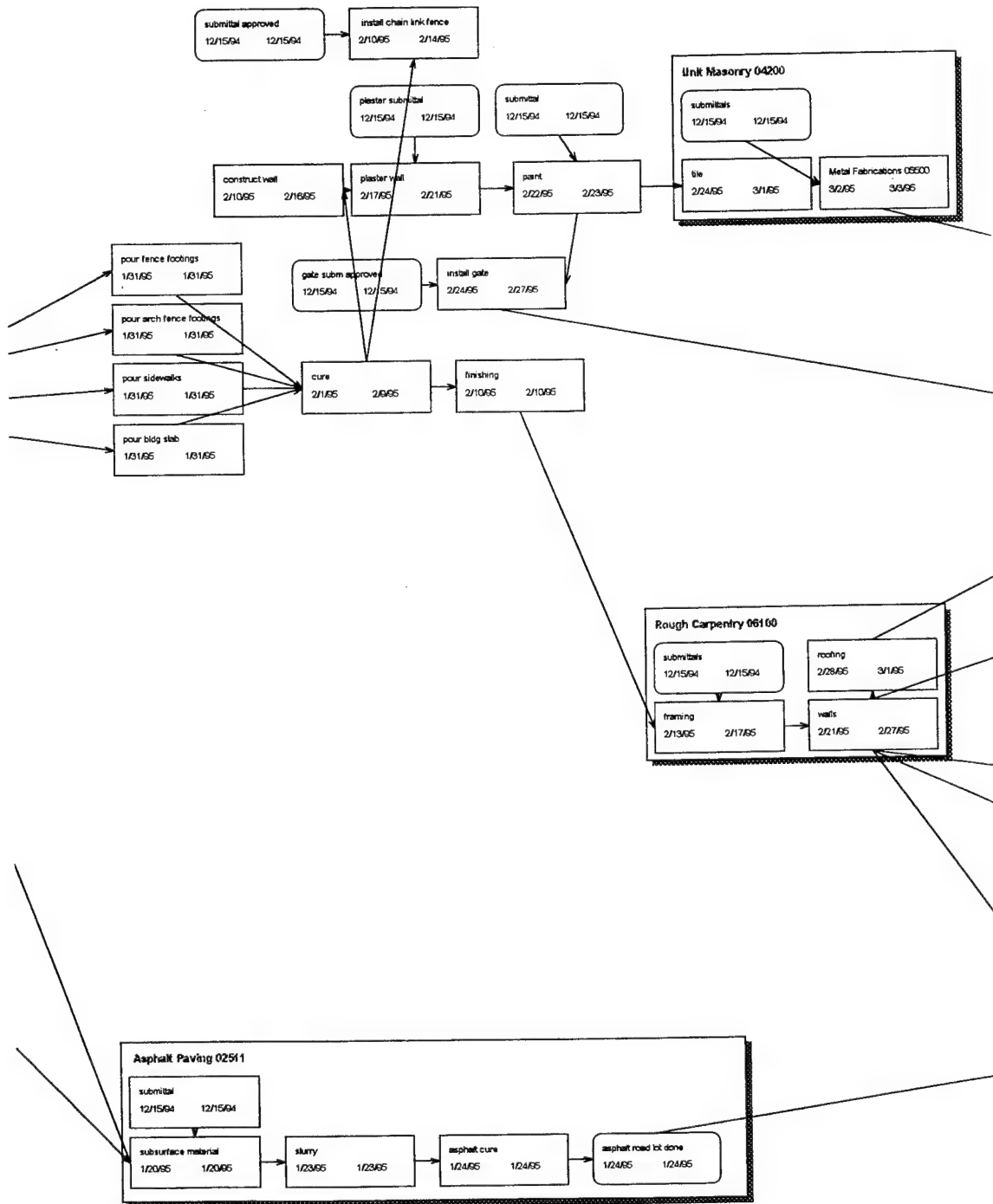


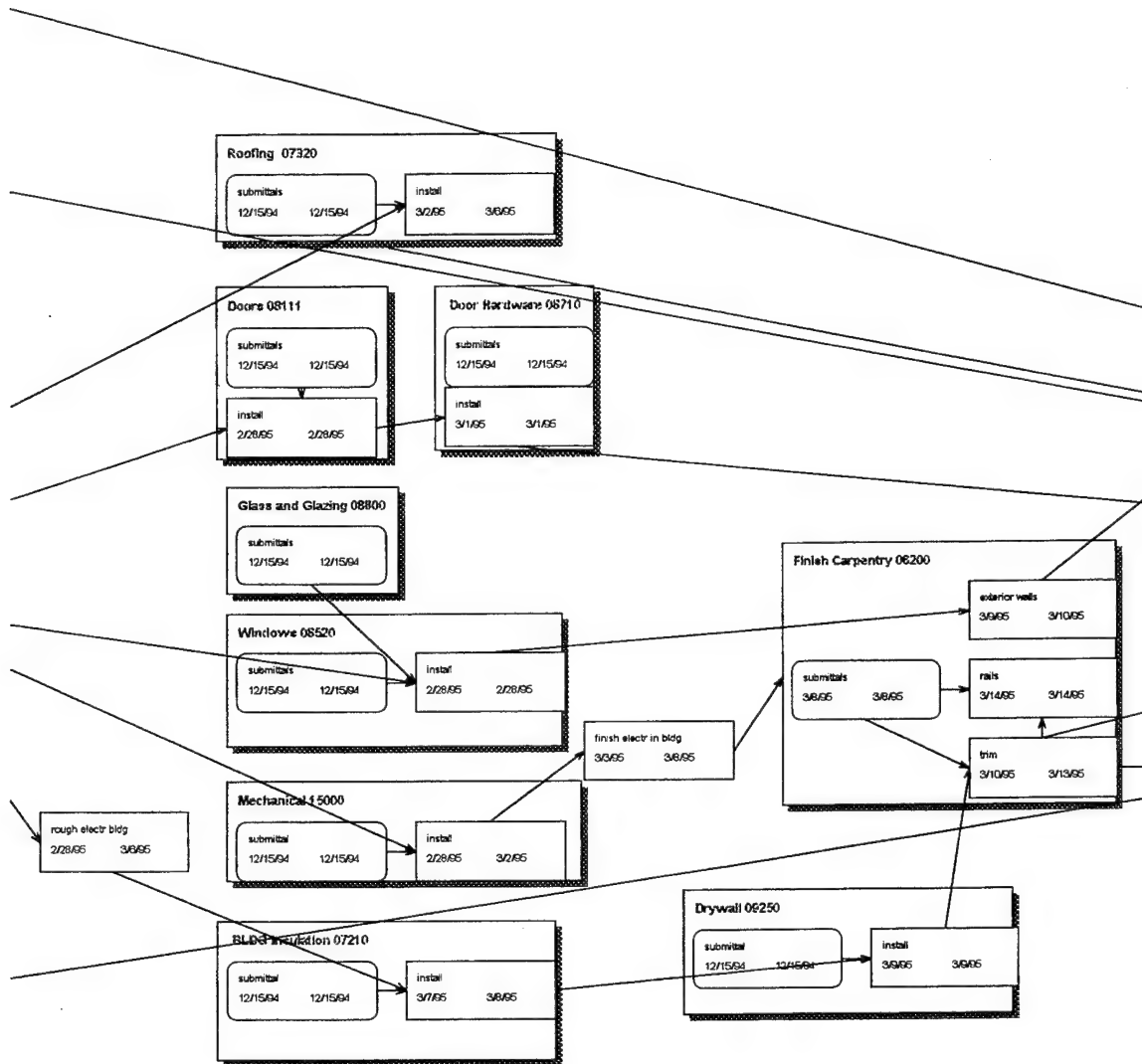




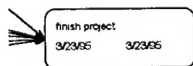












## LIST OF REFERENCES

- Ahuja, Hira N., Dozzi, S. P., Abourizk, S. M., Project Management, Techniques in Planning and Controlling Construction Projects, John Wiley & Sons, Inc., New York, 1994.
- Higgs, Scott., "PM for Windows (Computer Associates' CA-Superproject 3.0, Microsoft Project 4.0, Scitor's Project Scheduler 6.0, Symantec's Timeline 6.1)," Byte Magazine, Volume 20 P. 185-186, April, 1995.
- Moder, J. J., Phillips, Cecil R, Davis, Edward W., Project Management With CPM, PERT, and Precedence Diagraming, 3rd Ed., Van Nostrand Reinhold Co., New York, 1983.
- O'Brien, J. J., CPM in Construction Management, 4th ed., McGraw-Hill Inc., New York, 1993.
- Popescu, Calin M., Charoenngam, Chotchai., Project Planning, Scheduling, and Control in Construction, John Wiley & Sons, New York, 1995.
- Sanders, Norman., Stop Wasting Time, Computer Aided Planning and Control, Prentice Hall International Ltd., New York, 1991.
- United States Government, Office of Management and Budget, "Circular Number A-94", October 29, 1992.
- United States Government, Naval Facilities Engineering Command, "Economic Analysis Handbook, NAVFAC P-422", October 1993.



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